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ORIGINAL ARTICLES.

The Sedimentary and Volcanic Rocks of Western Togoland.

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Introduction.

In a former paper,[1] a short sketch of the geographical and geological features of Western Togoland was given. The main geological divisions, excluding recent deposits, may be tabulated thus :—

Divisions in order of superposition.	Estimated approximate thickness in feet as exposed in Western Togoland.
Oti Series	500
Buem Series	6000–8000
Togo Series	3000–4000
Crystalline Metamorphic Series	—

The Crystalline Metamorphic Series is predominantly of igneous derivation, and has been described in another paper.[2] We are here concerned with the rocks of the three sedimentary series. The Buem and Togo Series both contain intrusions of basic igneous rocks, and there is also a large development of contemporaneous volcanic rocks in the Buem Series. The Oti Series does not contain either extrusive or intrusive igneous rocks as far as at present ascertained.

Togo Series.

Flaggy, light coloured sericitic quartzites and quartzitic sandstones are the most common rocks in the Togo Series, but phyllites and mica-schists are usually interbedded with them. Apart from the more common flaggy sericitic quartzites, however, there is a saccharoid type which occurs in thick beds, in some places two to three hundred feet in thickness. It was noted at Tshome in the Dsawoe valley, where it occurs as an outlier forming a ridge amongst the Crystalline Metamorphic rocks, and on Gemi mountain at Amedzofe, whence it courses as a N.–S. ridge to above Vane. It is also well developed in the Adele Highlands, forming very conspicuous lines of hills between Shiare and Chirina. At Gemi it is a white saccharoid rock in hand specimen (160)[1] composed of very well rounded, water-clear, quartz grains ·02 to ·1 of an inch in diameter, in a matrix of fine angular clear quartz grains. There is slight iron-staining along cracks. The well-marked rounding of the individual grains makes it possible that the rock is of desert origin ; especially as the grains do not appear to show any pronounced strain as would be the case if the rounding were due to crushing.

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[1] Geol. Mag., Vol. LX, 1923, p. 490.

[2] Geol. Mag., Vol. LXI, 1924, p. 116.

The phyllites of the southern part of the Togo Range and of the Dayi Plateau vary much in appearance in the field. Perhaps the most common type is a light grey sericitic rock, but darker graphitic and hematitic varieties are found. They are well exposed around Amedzofe.

The equivalents of these phyllites in the Adele Highlands are greenish mica-schists. These are usually weathered on the surface to a brown friable earth which frequently retains the banded and puckered appearance of the fresh rock. Frequently in the higher ground between two streams the schist is decomposed to a depth of 10 to 20 feet, whilst in the stream channels the unaltered rock has been cut down to and exposed. It is on these stretches of weathered rock that lateritic deposits are most commonly developed.

A typical specimen of the mica-schist from a hill about a mile south of Bismarckburg (256) shows in thin section a mosaic of highly sheared and crushed grains of quartz, with lenticles and bands of fine sericitic mica throughout, accompanied by chlorite. One of the lenticles contains numerous tiny zircons showing rough outlines. The rock is obviously an altered sediment.

Another type of rock from a hill just south of Bismarckburg is a magnetite-schist (265). In hand specimen it is a heavy dark purplish spotted schist, the spots being light quartz areas in which tiny magnetite crystals are clearly visible. In thin section it shows shattered quartz with a little muscovite and green biotite, intimately intergrown with crystals and irregular grains of magnetite, accompanied by a little hematite.[2]

Typical of the quartzites of the Adele district, and, indeed, of the whole Togo Range, are those exposed on the road between Bismarckburg and Chirina (259 and 270). They are flaggy, white quartz-schists with a large development of sericite, accompanied by some chlorite along the foliation planes. A talc schist (261) is also recorded east of Bismarckburg on the Tolo road.

The Togo Series is undoubtedly the same as Hubert's Atacora series,[3] and the evidence in Dahomey, as in Togoland, is strongly

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[1] Figures in parentheses refer to specimens in the possession of the Gold Coast Geological Survey.

[2] Cf. J. D. Falconer, *Geography and Geology of N. Nigeria*, p. 110.

[3] H. Hubert, *Mission Sc. au Dahomey*, 1908, p. 350 *et seq.*

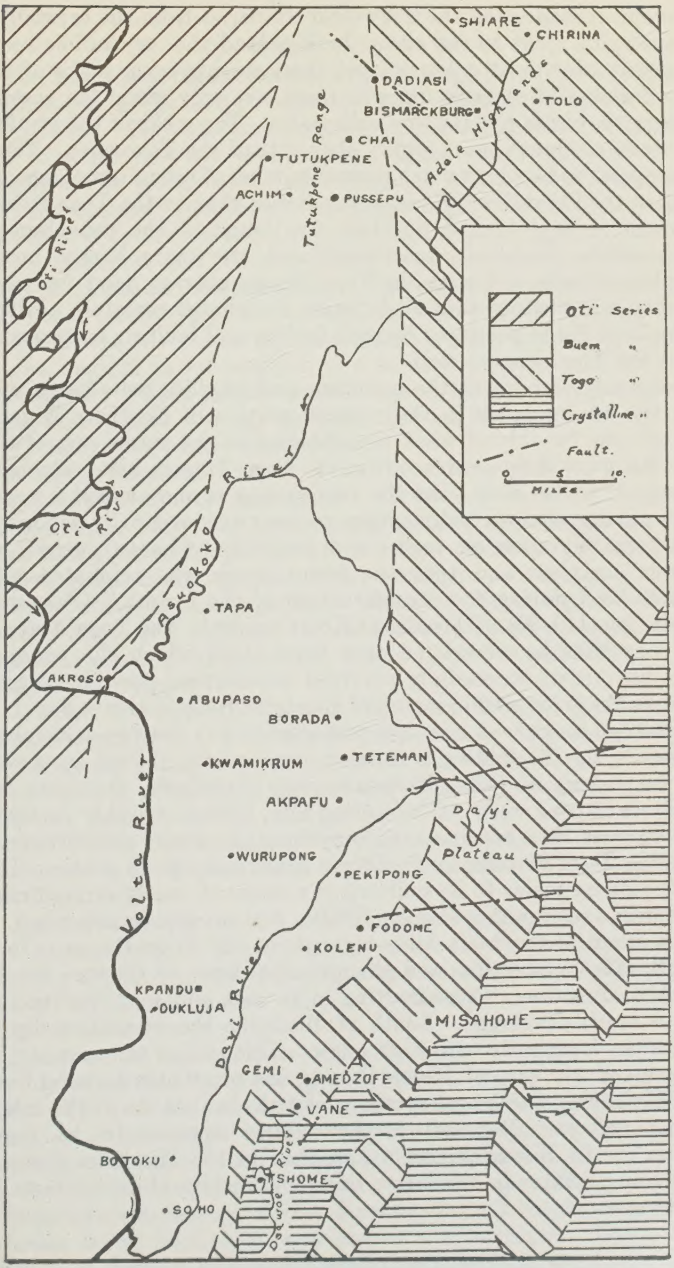

FIG. 1.—The Togo and Buem Series of Western Togoland.

in favour of separating the Togo-Atacora Series from the crystalline metamorphic rocks to the east. In Togoland the crystalline rocks are nearly always at a lower level than neighbouring rocks of the Togo Series, and seem to underlie these, not only along the eastern Togo scarp, but in the Dsawoe valley also. The rocks of the crystalline series are much more highly altered than the Togo ones. There also appears to be a very much greater number of intrusions of igneous rocks in the Crystalline Metamorphic Series than in the Togo Series.

Tracts of phyllite and quartzite are found in the peneplain of south-eastern Togoland, associated with the more highly metamorphosed rocks, but with the Togo Range near at hand for comparison, it is obvious that such tracts are almost certainly outliers of the Togo Series produced by such folding and faulting processes as affect the Togo Range itself.

Falconer's account of the quartzite and phyllite belts associated with the mica-gneisses in the western portion of Northern Nigeria reminds one forcibly of what is to be seen in the plains east of the Togo Range, and the evidence from the Togo-Atacora belt is strongly in support of his view that the two groups of metamorphic rocks " differ in age, that the sedimentary gneisses were originally deposited unconformably upon an earlier and probably archaean gneissic or igneous complex, and that the latter series was refoliated and recrystallized during the reconstruction of the former " (Falconer, op. cit., pp. 119–20). This also is Koert's view.[1] The Togo-Atacora belt may thus be considered as a tract along which the younger series have most successfully survived denudation, possibly in part owing to the great predominance of quartzitic rocks in this region.

The Togo rocks have not been subjected to any very great deforming forces, for the folding is in most cases gentle, though in one or two cases, e.g., at Gemi Mountain, near Amedzofe, the folds are tilted over to the west. The faulting also, though possibly reversed in some cases, does not amount to anything like severe overthrusting.

On the Dayi Plateau the folding is apparently quite gentle. The whole plateau seems to be built up of a series of nearly symmetrical folds with axes running N.N.E.–S.S.W., and no appreciable pitch.

The trend of the main folds throughout the Togo Range is in a N.N.E.–S.S.W. direction, and the principal lines of fracture are in the same direction. Cross-faulting in an east and west direction is not so much developed. South of Misahöhe the prevailing dip is eastwards, frequently at a high angle. This is also the case in the plateau country around Bismarckburg, the quartzites forming lines of hills running north and south, whilst the schists lie in the intervening valleys. Regional metamorphism appears to be more intense in the Bismarckburg region than in the Misahöhe district, what are phyllites in the latter being practically always schists in the former.

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[1] In H. Meyer, *Das deutsche Kolonialreich*, ii, 1910.

BUEM SERIES.

(*a*) *Sedimentary Rocks.*

The Buem Series is, in contrast with the Togo Series, predominantly argillaceous. The softer beds are well exposed at places in the Dayi valley. The sandstones are in most cases felspathic in character, and in places pass into coarse grits. Those which build up the hill ranges are in nearly every case bleached and silicified, sometimes forming compact quartzites ; but more usually the original grain of the rock is preserved and fragments of phyllite, quartz, quartzite, slate, limestone, and other rocks are to be seen scattered through a base of quartz and felspar grains. The cement is usually siliceous, but not invariably so. For example, a sandstone (112) found south of the Avode River near Fodome, shows almost nothing but quartz grains, angular to sub-angular, in a hematitic cement. A few small decomposed felspar grains occur here and there, and veins of clear secondary quartz with no hematite traverse the rock. There is no recrystallization of the original grains.

A highly felspathic variety is that of which a rock (225) found in the channel of the Asuokoko above Akroso may be taken as typical. It is a dark, fairly fine-grained aggregate of angular grains, more than half of them felspar in various stages of decomposition. Clear quartz grains make up most of the remainder, with a good deal of chloritic material and some mica. Between Wurupong and Kolenu, a rock (208) well exposed on the roadside shows rounded quartz grains in a finer grained matrix, chiefly of quartz and felspar. It is illustrated in Fig. 4 (*a*).

Another type of sandstone is that seen between Abupaso and Kwamikrum (215). It is coarse grained and composed chiefly of well-rounded grains of clear colourless quartz, with some white to brown grains probably of felspar and some flakes of mica, all in a siliceous cement. With further bleaching and veining it would probably pass into a quartzite very like the saccharoid type of Gemi in appearance. Similar rocks are found in the southern portion of the Dayi valley.

Indurated mudstones are of widespread occurrence, and in places are quite cherty or jaspery in appearance. One at Akpafu (119), forming the roof in one of the ironstone workings, is purplish grey in colour, and much veined. Similar rocks are found on the Akpafu ridge at other places.

About a mile south of Botoku, in the Kpandu Range, a very coarse pebbly sandstone is exposed, only about 2 feet thickness being seen. The pebbles, rounded to sub-angular, include grey limestone, granite, quartz-porphyry (?), phyllite, and jaspery and white quartzite. A similar rock occurs at Abupaso, east of Akroso. Here, in the bed of the Aboabo River, a greenish quartzitic sandstone, of which several feet are visible, dipping about 20 degrees south-east, overlies 20 to 30 feet of very coarse conglomerate. The pebbles vary from 6 inches in length downwards, and include granite, shale, slate, phyllite, mica-schist, vein-quartz, graphite-schist, and pyritic phyllite, all well rounded. The matrix contains many clear, rounded grains of sand.

Certain beds of pebbly grit a short distance south-east of Dukluja were regarded by Koert[1] as showing evidence of glacial conditions. Nothing of a convincing nature in support of this view was observed in the field. One of the finer grained types (380) is a coarse, dark grey, quartzitic grit, containing fragments of phyllite, schist, sandstone, etc., with smaller rounded quartz grains in a siliceous matrix. The coarse variety (385) shows pebbles of quartz, quartzite, phyllite, etc., up to several inches in diameter, in a matrix of angular to well-rounded quartz grains accompanied by much argillaceous material. It is greyish brown in colour.

In the country east of the Tutukpene Range two streams a short distance south of Dadiasi show purple phyllites, dipping at 40 degrees to the east. One band of these contains many clay-galls of different colours. A similar rock is exposed 8 or 9 miles further south. It is pale mauve to purple in colour, and contains yellowish-green to brown, altered, oval clay-galls, and also sheared quartz pebbles (251 and 286). These may represent a more advanced stage in the metamorphism of such pebbly beds as are found at Abupaso and further south.

Limestone is rare, except in close association with the volcanic belt, e.g. at Wurupong and in a tributary of the Ataulo between Kpandu and Dukluja, in both of which cases it is interbedded with basic volcanic tuffs. Kitson[2] records several beds of grey and yellow limestone associated with quartzite and conglomerate near the junction of the Afram and Volta Rivers, north of Pessi. These may be similar to the Togoland examples.

The rocks of the Buem Series dip at a high angle to the east in practically all cases, the hill ranges being formed by the more quartzitic portions of the succession, probably aided by N.–S. faulting. For instance, the Tutukpene Hills seen from the north show a series of scarps and dip slopes, all the scarps on the western side. The structure is not very pronounced, but quite definite, and the range appears to consist of a series of quartzitic sandstones with a few softer argillaceous beds, all dipping steeply to the east and becoming vertical on the eastern side. To the east of the range the strata in the low country contain a large proportion of argillaceous beds.

The chief problem connected with the Buem Series, however, is its relationship to the Togo Series. As Koert suggests,[3] the presumption is in favour of a fault line along the foot of the western side of the Togo Range, bringing Buem rocks down against the Togo series. Lithologically there is a clear distinction between the Togo and the Buem rocks in the Dayi region, though it is not quite so obvious in the Tutukpene-Adele region. Nothing quite like the felspathic sandstones or the jaspery quartzites of the Buem region is found on the Togo Range; nor is there anything in the Togo Series to match the conglomerates with igneous and metamorphic pebbles which are found all along the line of hills from Soho to Tapa, or the phyllites with clay-galls seen in the Tutukpene region. Hubert's evidence in Dahomey,[1] however, makes it appear almost conclusively that the Gourma series (equivalent to the Buem series of Togoland) is different from and younger than the Togo-Atacora Series. In the Gourma region both the Gourma sandstones and the Atacora quartzites are seen to rest on the Crystalline Metamorphic Series, and only the Atacora rocks are metamorphosed and folded along with the crystalline schists. There is therefore good reason for keeping the two series apart in Togoland. The succession of the Buem rocks is probably interrupted by one or two repetitions due to faulting, making the total thickness of strata appear much greater than it really is.

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[1] W. Koert, *Beiträge z. geol. Erforsch. d. deutsch. Schutzgeb.*, H. 1, 1913, p. 17.

[2] A. E. Kitson, *Rep. Gold Coast Geol. Surv. for* 1915, 1917, p. 6.

[3] W. Koert, op. cit., p. 15.

(*b*) *Intrusive Rocks.*

Three intrusions were met with in the Buem Series, all of much altered basic rocks.

(1) Half a mile north of Teteman, in the Akpafu Hills, on the road to Borada, a serpentine is exposed on the hillside. Nothing is shown which could guide in deciding how it is related to the sedimentaries. It is much sheared, the foliation-planes dipping east, and in general disposition it appears to lie parallel to the bedding-planes of the sandstones near at hand. In hand specimen the rock (139) is a mottled olive-green to yellow serpentine, with no original mineral traceable. It shows large bastite crystals along with patches of serpentine with mesh structure containing more iron staining than the bastite, the whole being much veined with serpentine. It is quite like the Djeti serpentine, and almost certainly an altered peridotite.

The other two occurrences are in the Tutukpene region.

(2) At a mile and a half to the south-east of Chai town, an altered basic rock outcrops in a stream bed. It appears to form an intrusive mass in the phyllites, but is of no great size, perhaps about 200 to 300 yards by 100 yards.

It is in parts completely serpentinized (284) and quite like the Teteman rock, but some of it is less altered (285) and appears in hand specimen to be a coarse-grained gabbro, showing bluish-green saussuritized felspar and black crystals of diallage. It is seen in thin section to be a coarsely crystalline granitic aggregate of diallage and felspar, the individuals being up to about a centimetre in diameter. The felspar is nearly all quite altered to saussurite veined with chlorite. The pyroxene is mostly altered to serpentine and chlorite, the decomposition taking place initially along the cleavage planes and resulting in tiny fragments of unaltered mineral in a matrix of secondary matter. A very little iron ore is also present.

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[1] H. Hubert, op. cit., p. 414.

(3) About 2 miles east of Achim, on the road from Pussepu to Tutukpene, a much altered dolerite is exposed. The outlines of the mass are irregular. In the centre it is coarsely crystalline. Near where it comes in contact with the quartzitic sandstones which surround it the texture changes, and it becomes compact and flinty in appearance. This is probably a chilled edge. There is at least half a square mile of this dolerite, possibly more, and it seems to be elliptical in cross-section. In one stream flowing towards Achim, the rock is quite decomposed, forming a serpentinous mass.

Under the microscope the rock is seen to be an ophitic dolerite (292) consisting originally of augite and felspar.

The augite is still fresh, and in many cases hypidiomorphic. It is pale brown in colour, but slightly darker round the edges of the crystals. Large composite augite crystals contain up to half their volume of small felspar laths arranged longitudinally, producing a " cervicorn " structure, such as is typical of certain quartz-dolerites. This suggests that the rock is a quartz-dolerite, though the alteration it has undergone is too great to permit of a definite decision. Large felspar laths are also plentiful throughout the slide with augite crystals partially enclosing them. The felspar is highly saussuritized and very cloudy. There is a good deal of iron ore in small crystals. The rock is greenish, decomposed-looking, and of medium grain in hand specimen, weathering with a brown crust. It is in places altered (297) to a light greenish-yellow mottled serpentine. The chilled edge of the mass (295) is a dark olive-green compact rock in hand specimen with rather cherty fracture, and is very fine-grained as seen in thin section. It shows irregular sheaves of tiny augite and felspar laths in a dark green chloritic groundmass. The felspar is much altered, and there are veins of secondary quartz. There may be a little glass, but even when quite fresh it did not contain much.

There is nothing in the Buem Series of Togoland corresponding to the large intrusions of plutonic rocks found in the equivalent Birrim Series of the Gold Coast, as pointed out by A. E. Kitson. Those in Togoland are comparatively small and insignificant and have produced no appreciable contact metamorphism in the Buem sediments. It is quite probable that these intrusions are contemporaneous with those on the Gold Coast.

(c) *Nkunya and Kpandu Volcanic Group.*

The most interesting feature of the Buem Series is the volcanic development in the Nkunya and Kpandu region (Fig. 2). Rocks ranging in character from rhyolite to olivine-basalt were found in this area, but the predominant types are olivine-free basalts, and the extreme acid and basic volcanic rocks are comparatively uncommon.

There is also a large development of volcanic agglomerates and tuffs.

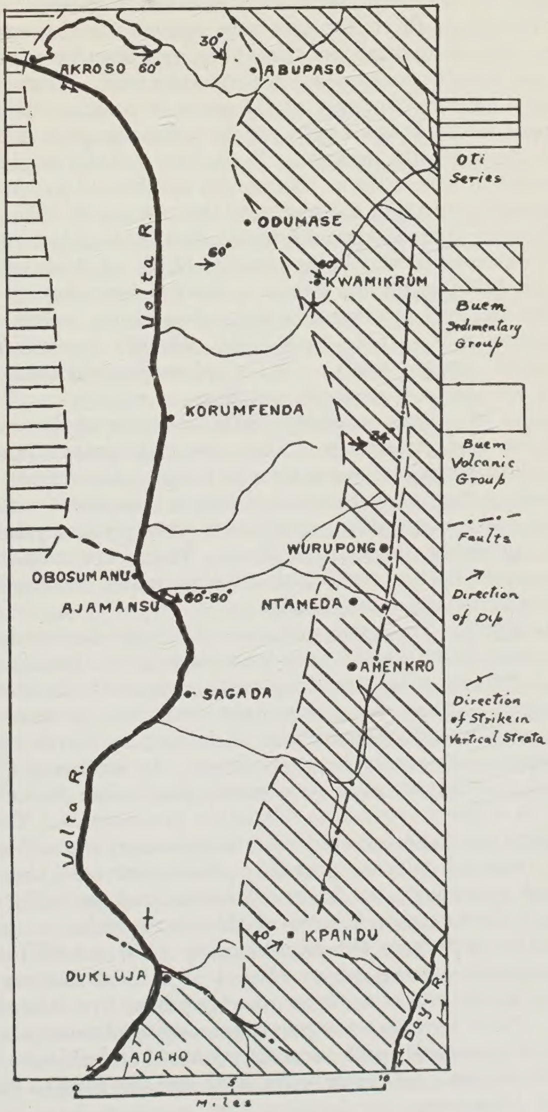

FIG. 2.—The Buem Volcanic Group of Western Togoland.

The examination of the district makes it certain that the volcanic rocks are contemporaneous. Also, unless the Buem Series has been overturned since its deposition, which is extremely unlikely, the volcanic activity took place during the deposition of the first half, or third, of the Buem Series as exposed in Togoland.

RHYOLITE.—Rhyolites were only met with in the northern portion of the volcanic district, but there they were found in several localities, and are usually conspicuous rocks in the field. That forming a hill range a mile or two west of Odumase is perhaps the most typical (453 and 457). It is a bright red to yellowish-green brecciated rock much veined with quartz. It shows well-developed spherulitic structure in thin section. Numerous specks and patches of iron ore, apparently hematite, are scattered throughout it. The same type of rock occurs in the low ground to the west of the ridge. A similar rock (400) outcrops in the Volta channel N.W. of Ajamansu. Another rhyolite (420) found in a stream a short distance east of Ajamansu is a white and grey mottled rock in hand specimen, veined with quartz. In section it is seen to be a light coloured devitrified glass with numerous perlitic cracks. It is microspherulitic in some parts. There are also some chlorite patches.

Blocks of quartz-porphyry (393) occur in agglomerate between Ntameda and Ajamansu. They are pale greenish-grey compact rocks with conspicuous quartz and felspar phenocrysts. Under the microscope they show sheaves of felspar microlites, with intergrown quartz, and in some places a yellowish-green cryptocrystalline groundmass, probably devitrified glass. There are numerous felspar phenocrysts, both of orthoclase and plagioclase. Quartz is abundant, both as blebs and interstitially.

TRACHYTE.—Trachytic rocks are not very common, but several types were found on the road from Sagada to Ahenkro, where they form a distinct ridge trending north and south about 2 miles east of Sagada. They are fairly light coloured greenish-grey rocks (474 and 475) with phenocrysts of felspar and with light greenish amygdales, as seen in hand specimen. In section they show well-formed phenocrysts of felspar, partly plagioclase, but chiefly orthoclase, in a finely crystalline felspathic groundmass. There is some chloritic material associated with the phenocrysts, and some sphene. Thin veins of felspar, probably albite, traverse the rock. The greenish amygdales are finely crystalline and probably chalcedony. Some of them contain sheaves of chlorite crystals.

Another type from the same locality (476 and 477) is more basic and probably a keratophyre (Fig. 4 (*b*)). It is not very fresh, but shows phenocrysts of a felspar, mostly albite, in a felspathic groundmass. There are also some pale green augite phenocrysts, frequently nearly idiomorphic, with secondary quartz and chlorite, and a good deal of iron ore. A riebeckite-trachyte was also found a short distance east of Ajamansu.

BOSTONITE.[1]—A typical bostonite (374) (Fig. 4 (*c*)) occurs east of the Kpandu-Dukluja road. It is a light brownish-red rock in hand specimen, appearing to consist almost entirely of felspar laths. These, as seen in thin section, have the brownish mottled appearance characteristic in such rocks, and are grouped together in radiating sheaves, this structure being very perfectly developed in some places. Chlorite fills the spaces between the felspar laths, and in it are numerous tiny spheroids of clear secondary (?) albite, usually with a chlorite centre. There is a fair amount of dusty iron ore throughout the felspar, and a little calcite. A similar but rather more fine-grained rock (350) occurs on the Kpandu-Dukluja road near by.

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[1] My attention was drawn to this rock by Dr. H. H. Thomas.

DOLERITE AND BASALT.—The decomposed state of a large proportion of these rocks makes it advisable to describe them according to their localities rather than under rock types.

Abupaso.—At the Ajanafi River, north of Abupaso, there is an extensive exposure of volcanic agglomerate, varying from fine to very coarse in texture. The blocks composing the coarse agglomerate are chiefly of basic types, though some of intermediate character also occur. There is much scoriaceous rock in some parts. Near the western side of the exposure what is probably a dyke of fine-grained basalt is visible coursing northeast-southwest. South of this a porphyritic basalt occurs in a large mass which may be a plug or another dyke. On the eastern side of the agglomerate occurrence, which is about three-eighths of a mile broad, brown mudstones are exposed, veined with quartz and dipping eastwards at moderate angles. Along with them appears in several places a crystalline siliceous limestone, light grey in colour and much veined. The limestone appears to be in lenticular patches striking north and south. The great majority of the igneous rocks, both those occurring as lavas and those which appear as blocks in the agglomerate, are much decomposed, and the original ferromagnesian minerals in particular are seldom preserved. Calcite and chlorite are abundant throughout the rocks. Types with porphyritic felspars are common, but the phenocrysts are in most cases, entirely, or almost entirely, replaced by calcite.

Of those rocks which are not so highly decomposed, one common type (345) is a grey, fresh-looking rock with conspicuous felspar phenocrysts in a compact base. In section it shows large phenocrysts of labradorite, sometimes fairly fresh, in a fine holocrystalline groundmass of felspar laths, magnetite, and calcite. There are also fairly large cavities filled with calcite, sometimes accompanied by chlorite. There is no fresh augite in the rock. A rock similar to this (445) forms the plug-like mass mentioned above.

Another basaltic rock from the same locality, occurring both as blocks in the agglomerate and as lava flows, is a compact dark green rock in hand specimen with greenish phenocrysts of augite and purple calcite amygdales (443 and 344). In thin section it shows small phenocrysts of augite and of felspar in a holocrystalline, medium to fine-grained groundmass. The augite is partly fresh and partly altered to chlorite. The felspar of the phenocrysts is in laths which are in most cases completely decomposed, and in some cases replaced by calcite. When fresh it is mostly untwinned, but probably is labradorite from its refractive index. The groundmass is of the same minerals with much iron ore. In some instances the felspar of the groundmass seems fairly fresh. Calcite and chlorite occur in cavities.

A dark basaltic rock (447) found in the Aboabo River, just south of Abupaso, shows a dark groundmass of felspar microlites with fresh granules of augite and much magnetite. In this are completely decomposed phenocrysts and also numerous calcite, chlorite, and chalcedonic amygdales. The phenocrysts are mostly dark with secondary iron oxide. Some lath-shaped ones were obviously felspar originally. Others of serpentinous material have outlines suggesting olivine.

Odumase.—Here one of the chief types (450) is a dark greenish purple compact basalt in hand specimen, showing small lath-shaped felspar phenocrysts and calcite and chlorite amygdales. In section it shows stumpy phenocrysts of labradorite, with rather smaller prisms of augite and laths of labradorite, in a dark matted holocrystalline base of augite, felspar, and iron ore, with a good deal of chlorite. The augite is clear and fresh ; the labradorite is a good deal spotted with decomposition products. Another rock (452) a short distance south of Odumase is similar in type. Von Ammon[1] describes a volcanic rock from some place in this neighbourhood.

Farther on along the road to Korumfenda what appears to be an olivine-basalt occurs (458). It is a dark mauve-coloured rock in hand specimen, compact in appearance, with dark green phenocrysts. Some of these under the microscope appear by their shape to be almost certainly pseudomorphs of serpentine (often with chalcedony) after olivine, whilst others may be after felspar or augite. The groundmass is of small augite and felspar laths. The small augite crystals are rectangular in cross-section and undecomposed. They are set in a sheaf-like network of tiny felspar laths, with tiny amygdales of chalcedony, sometimes accompanied by chlorite.

Wurupong Scarp.—At Wurupong there is a good section exposed in the stream flowing from the scarp. Below the thick quartzitic sandstones which form the ridge is a succession of tuffs and lava flows interbedded with sediments, the whole apparently dipping eastwards at about 30 degrees.

One bed of dolerite over 20 ft. thick (368) is a dark green fairly compact rock in hand specimen. In section it is seen to be a medium-grained fairly basic rock, the chief constituent being fresh brown augite accompanied by altered felspar. There are also small patches of chlorite throughout the rock, and a good deal of calcite. The augite, which is a titaniferous variety, is sub-idiomorphic. It has usually a light-coloured, often hour-glass shaped, centre, surrounded by a darker, purplish-brown pleochroic zone. The felspar is in no case fresh. The individuals are in some cases arranged variolitically.

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[1] L. von Ammon, "Zur Geologie von Togo und vom Nigerlande": *M. d. Geogr. Ges. München*, i, 1905, p. 429.

Ajamansu.—About 2 miles east of Ajamansu a conical hill rises some 500 feet above the level of the surrounding plains. It appears to be a plug of dolerite, and is surrounded by coarse agglomerate, chiefly composed of basic fragments—many of them scoriaceous. The dolerite (404) is fairly coarse-grained in hand specimen. The only fresh constituent is felspar (andesine) in large and small laths, accompanied by fine magnetite grains in a chloritic and calcitic base. The original augite is replaced by chlorite pseudomorphs. The structure appears to have been intersertal. The felspar laths seem completely albitized. They are in places largely replaced by calcite. The chlorite and calcite also occur as amygdales. Practically the same rock type occurs at Obosumanu on the opposite side of the Volta River (401) associated with rhyolite.

On the hill east of Ajamansu, but not seen in situ, was found a picrite (405). In hand specimen it is a dark, coarse-grained rock, and is composed of large brownish augite, and colourless olivine crystals up to half-an-inch in diameter, in a groundmass of smaller anorthite, augite, and olivine crystals. No glass is present. Serpentinization of the olivine is fairly well advanced, and has largely obscured the mutual relationships of the minerals, but the olivine appears in some cases to be idiomorphic towards the augite, which is also moulded on felspar laths. The augite sometimes completely encloses small olivine crystals. It is slightly pleochroic, and in most cases fresh. The anorthite is in small laths and fresh, or nearly so.

Associated with rhyolites and tuffs in a stream a short distance east of Ajamansu is a fairly fine-grained basalt (419) showing felspar laths with a tendency towards variolitic structure in a decomposed chloritic base. There is much magnetite in grains throughout the rock. The felspar is brownish in colour and almost completely albitized. Only a very few of the rocks met with in the volcanic group show this feature. There is a good deal of interstitial secondary quartz.

One of the rocks found on the Ntameda-Ajamansu road (421) is a dark greenish-grey basic-looking dolerite in hand specimen, showing large dark felspar phenocrysts and weathering with a dark brown crust. It is seen to be fairly coarse grained in thin section, and the large felspar crystals constitute the bulk of the rock. They are much decomposed and lie in a groundmass of small fresh pale-brown augite crystals, decomposed felspar laths and much magnetite, with chlorite in patches. Some of the small felspar laths in the groundmass are fairly fresh.

The second stream on the road from Ntameda to Ajamansu yields still another type of basalt (390). It shows a few phenocrysts of nearly fresh labradorite—some of them being corroded skeletal or semi-skeletal crystals—in a fine-grained groundmass composed of tiny fresh felspar laths and much magnetite, with chlorite and calcite. The latter minerals also replace some of the phenocrysts. There are also tiny granules of epidote in the groundmass.

North of Sagada the stream sections show exposures of weathered lavas and agglomerates. The former are in most cases fine-grained basalts.

Kpandu and Dukluja.—Between Kpandu and Dukluja there are numerous lava flows interbedded with tuffs. One type is a dolerite (353), light grey and speckled in hand specimen, and weathering with a hard brown crust. Irregularly grouped labradorite laths form more than half the rock, and are the only fresh constituents. The augite is entirely altered to chlorite and calcite, which fill the angular spaces between the felspar laths and show no trace of the original mineral. There is much magnetite scattered through the rock.

Another rock (371) east of the Kpandu-Dukluja road is a dark, fine-grained basalt in hand specimen, and shows a fine matted intergrowth of long thin felspar rods with much iron ore and chlorite. Only the felspar is fresh and appears by its extinction angles to be andesine. Many of the felspar rods have black cores of iron ore. There are also a few stumpy felspar phenocrysts which appear to be acid labradorite.

Another rock (375 and 377) found near this last is an altered olivine-basalt, showing large, well-formed phenocrysts of augite, felspar, and serpentine after olivine, in a holocrystalline base of augite and felspar with much magnetite. The augite both in the groundmass and in the phenocrysts is fresh and light in colour. The original presence of olivine is almost certain from the characteristically shaped pseudomorphs of dark brownish-green serpentinous material with magnetite dust throughout. The stumpy, lath-shaped felspars are completely decomposed.

A rock which crops out in the Volta at Adaho, south of Dukluja (482), is a highly altered basalt full of calcite amygdales.

TUFFS.—Throughout the length of the Nkunya and Kpandu volcanic belt the lava flows are accompanied by tuffs, frequently highly decomposed, but in some cases fresh. They vary from very fine-grained rocks to coarse agglomerates. One of the most typical of the fine-grained tuffs is that found beneath the Nkunya scarp at Wurupong (364). It consists of small angular fragments of various kinds of basalt, together with broken crystals of augite in a decomposed serpentinous base, some of it possibly originally glassy. There are numerous spherules of chlorite and of calcite, and some pseudomorphs of serpentine after olivine. A similar tuff (418) occurs in a stream east of Ajamansu.

A sandy variety was found near this last (407). In section it shows rounded quartz grains with basalt and augite fragments, and some calcite. In hand specimen it is a dark greyish-blue fairly fine-grained rock showing rounded grains of clear quartz in a dense matrix. A more calcareous variety (358) occurs as a patch in a lava west of the Dukluja-Kpandu road. It is a fine-grained to compact greenish rock, limy in appearance, and shows under the microscope small angular fragments of basalt and basaltic glass with some quartz grains in a calcite matrix.

A trachytic tuff occurs on the Sagada-Ahenkro road associated with trachyte and keratophyre (478). It is a dark green rock, medium in grain. Most of the fragments show crystals of completely decomposed felspar and of subordinate fresh augite in a glassy base. Some are darker in colour and cryptocrystalline. They appear to be set in a glassy matrix, and in all probability the rock is the brecciated chilled edge of a lava flow with some foreign material in it rather than a tuff proper.

Along with the tuffs may be mentioned the crystalline limestones (442) associated in several localities with the Buem volcanic rocks. That found north of Abupaso is typical of such beds. It is a bluish grey compact veined rock, weathering with a yellowish-grey crust. In section it is fine in grain and consists of a mosaic of calcite crystals with veins of coarser-grained calcite traversing it. There does not seem to be any other mineral present. Another in a stream bed south-west of Odumase (455) is similar.

From the above description of the rocks of the Nkunya and Kpandu volcanic group it will be seen that rocks of basaltic composition greatly predominate. Olivine-bearing types, however, are rare. This point corresponds with the rarity of olivine-bearing dolerites and basalts in N. Nigeria.[1] No felspathoid-bearing rocks were met with.

The texture varies much in the different dolerites and basalts, but ophitic texture is quite uncommon. A microlitic type of texture is possibly the most common, but in places it is intersertal or intergranular. There seems to be no general rule governing the decomposition of the two chief minerals. In one case the felspar may be completely decomposed, and the augite unattacked, whilst in quite a similar rock from the same locality the felspar is fresh, and there is no trace of the original augite.

The doleritic rocks from the Gourma district described by Hubert (op. cit., p. 475) may represent a continuation of the Nkunya and Kpandu volcanic belt to the north.

It is noteworthy that amongst the many lavas of the Nkunya and Kpandu area not one was found which could be called an andesite. The felspar is in some cases andesine, and is very seldom more basic than intermediate labradorite, but the general aspect of the rocks in hand specimen, the abundance of magnetite, the generally large proportion of augite, or its decomposition products, and the texture as seen in thin section, makes it advisable to group them all together.

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[1] J. D. Falconer, op. cit., p. 140.

Hubert,[1] on the other hand, in reviewing the eruptive rocks of the Niger basin, draws attention to the abundance of andesitic rocks, and the comparatively subordinate position of more basic types.

The volcanic rocks along the course of the Volta appear to have been noted first by Ferguson,[2] but he is not very explicit regarding the portion of the river course in which they occur. More recently Kitson [3] has located the volcanic belt with greater accuracy.

OTI SERIES.

The country occupied by the Oti Series is practically reduced to base-level, as is shown by the winding of the river (Fig. 3), but the absence of hard rocks has prevented the production of isolated mountains. It is not necessary, however, to assume from the facts at present known, that this area has ever stood high since the deposition of the series. Low, undulating park land characterizes the whole area. There is in many cases a succession of terraces leading up from the Oti River flats to the level of the surrounding country, due to the differential weathering of the harder and softer members of a horizontal series of rocks.

A rock (318) outcropping between Langanja and Adibo on the road from Krachi to Yendi may be taken as typical of the arkoses which build up a large part of the Oti Series. It is a fine-grained rock, consisting of angular fragments of quartz, felspar, biotite, and chlorite with a little augite in a very fine base of similar material. The felspar seems the most abundant constituent, and is in many cases fresh. A good deal of it shows lamellar twinning, and the low refractive index indicates a fairly acid plagioclase, but there seems to be much orthoclase also. There is some apatite and zircon and much magnetite. A similar rock (338) but with a fair amount of calcareous cement, and some little fragments which look like decomposed basalt, occurs interbedded with white earth at Jankpima. Von Ammon [4] describes others of these rocks.

At Jankpima, east of Yendi, the ground falls away steeply to the Oti flats, and about 200 feet of strata are imperfectly exposed. They are practically horizontal and are mainly sandstones, but near the top two beds of a white to yellowish compact earth are exposed, about 25 feet apart. Each of them is 2 to 3 feet in thickness, with sandstone above and below. The earth is very absorbent, weathering grey or brown. The purer white earth (335) is a very fine-grained compact absorbent rock composed of minute grains of crystalline material with low double refraction. The refractive index of most of the particles is about 1·53 or slightly higher. Comparison with the accompanying more impure earth (339) and with the associated arkose makes it practically certain that the fine white

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[1] H. Hubert, *Compt. Rend.*, clii, p. 1606.

[2] In Knox, *Geol. of Africa*, 1905, n. 318.

[3] A. E. Kitson, *Rep. Gold Coast Geol. Surv. for* 1915, 1917, p. 6.

[4] L. von Ammon, op. cit., pp. 419–20 and 426–7.

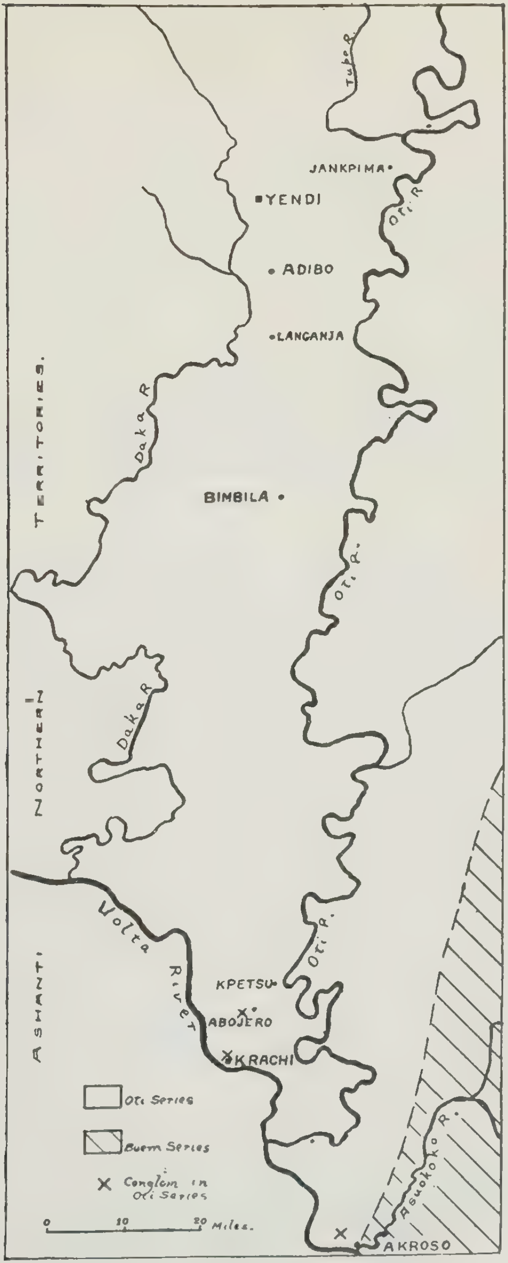

FIG. 3.—The Oti Series of Western Togoland.

earth is chiefly felspathic powder, produced by the breaking up under arid conditions of the original crystalline rocks from which the Oti sediments have been derived. The coarser felspathic material seems to have gone with the quartz and ferromagnesian minerals to form the arkoses with which the white earth is associated. Specimens found at Jankpima show the pure earth, the medium-grained arkose, and the intermediate rock showing the minerals of the arkose in a groundmass of felspathic powder. The fresh state of the felspar in this locality, and also in the majority of the Oti arkoses points strongly to the conclusion that the igneous or metamorphic rocks from which the material for the Oti rocks was derived were denuded under desert conditions. It is certainly highly improbable that fresh felspar would attain in any other way such a fine state of subdivision as it does in the Jankpima earth.

The conditions under which the Oti sediments were laid down, however, were probably estuarine, as the bedding is predominantly regular, and ripple-marked sandstones are found. Quiet stretches of water would also be necessary to allow of the fine felspathic dust settling in regular beds covering an area of at least several square miles.

Limestone bands were found in the channels of the Tanja and Tupe Rivers. That from the first (328) is a grey argillaceous-looking rock in hand specimen. In thin section it is seen to be an impure crystalline limestone, having many tiny quartz, chlorite, and sericite fragments in a matrix of interlocking calcite crystals. The separate calcite crystals are only clearly discernable under crossed nicols. That from the Tupe River (331) is similar, but purer, with only a few quartz and muscovite particles. The rock is full of calcareous sponge spicules. These have been examined by Mr. C. P Chatwin, who reports that they yield no evidence of the age of the deposit.

The conglomerates and conglomeratic sandstones of the Oti Series are chiefly to be seen to the east and south-east of Krachi. In the bed of the Bonda River fine-grained horizontal sandstones outcrop. Above, on the hill-slope, coarse conglomerate is visible. It forms a ridge coursing north-eastwards from Krachi to Kpetsu. In the Volta river at Krachi the same conglomerate is exposed, and below it appears the fine-grained sandstone seen in the Bonda channel.[1] On the road from Krachi to Kpetsu coarse conglomerates are extensively exposed. Quartzite, sandstone, slate, and phyllite pebbles are the chief constituents.

Between Abojero and Kpetsu the finer sandstones lower down in the series are seen at several points, and these form the lower portions of the ridge of small hills west of the road. The top 100 feet or so is of coarse conglomerate. Here discoidal granite pebbles are frequent, together with quartzite, gneiss, and sandstone ones. One block of veined Buem sandstone measured 2½ by 2 by 1½ feet, but this is much larger than the average.

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[1] See also L. v. Ammon, op. cit., p. 426–7.

A mile and a half north of Akroso on the Krachi road, coarse conglomerate is again exposed, lying horizontally. It contains pebbles of quartzite, of Buem Sandstone like that exposed in the Asuokoko River and further south, and of granite or granitic gneiss.

A rock intermediate between the conglomerates and the sandstones of the Adibo type is to be found just east of Kpetsu on the slope down to the Oti river. It is a coarse grit made up chiefly of angular to rounded quartz grains. There are also small mudstone fragments. Similar rocks are to be seen at Krachi associated with the conglomerates

The Oti Series extends into Gold Coast territory, where it covers large tracts of ground, and is known as the Kwahu Series. Hubert[1] tentatively associates the Eocene deposits of the Niger basin with the Oti-Kwahu Series, but no evidence of age has as yet been found in the series itself. On the other hand, Kitson[2] suggests a Devonian or Carboniferous age from lithological comparison with beds on the Gold Coast. It is impossible to commit oneself definitely to either view, however. Hubert's linking up of the Niger and Oti beds by means of a narrow strip of colour across the Gourma plains does not rest on any certain evidence.

The Oti Series is certainly quite distinct from the Buem and much younger. On the Gold Coast[3] it is seen resting unconformably on Buem rocks. In Togoland they were seen within a mile or so of one another at some places, but never in contact. The lack of regional metamorphic alteration in the Oti rocks, however; their inclusion of pebbles which seem almost certainly derived from the Buem rocks; their undisturbed nature quite near the junction; the original nature of the rocks themselves; the absence of volcanic activity in the vicinity of those Buem regions affected by it—all these, though of little weight singly, make it almost certain that in Togoland also the Oti series rests unconformably on the Buem Series. The approximate position of the junction is shown by a scarp of Buem rocks in Togoland, but there is no such scarp on the Ashanti side of the Volta, south of Akroso. The scarp may be due to faulting. It is equally possible that it existed prior to the deposition of the Oti beds.

SUMMARY OF CONCLUSIONS.

(1) Three distinct series of sedimentary rocks are recognizable in Western Togoland, but in no case has any definite evidence of age been found.

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[1] H. Hubert, *État actuel de nos Connaissances sur la Géologie de l'Afrique Occidentale*, ed. 2, 1919, p. 10.

[2] A. E. Kitson, *Rep. Gold Coast Geol. Surv. for* 1917, 1919, p. 4.

[3] A. E. Kitson, *Rep. Gold Coast Geol. Surv. for* 1919, p. 6.

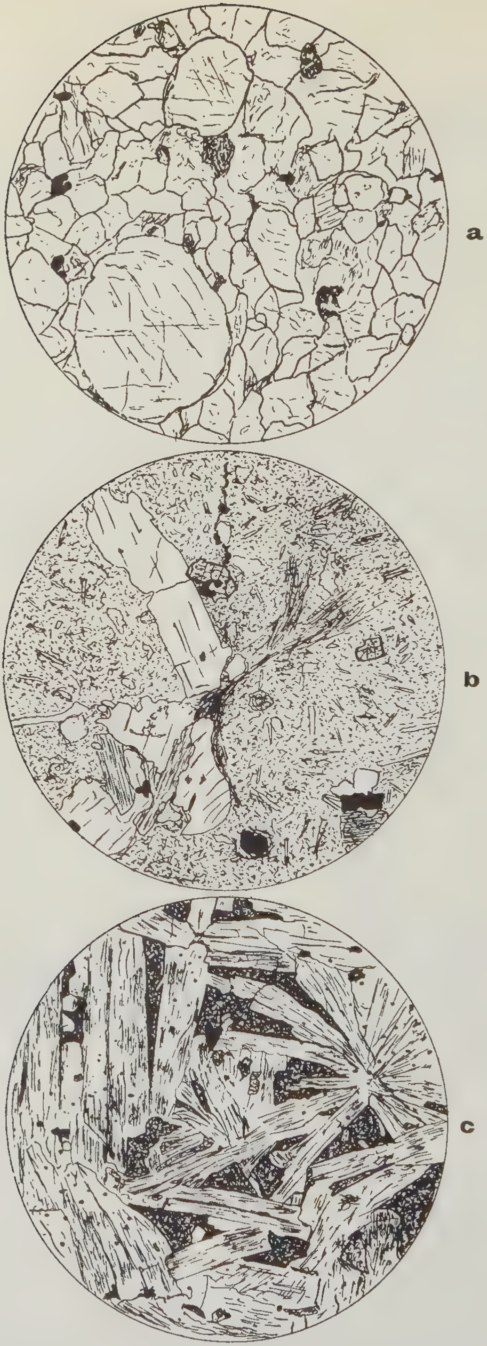

FIG. 4.—Sections of sedimentary and volcanic rocks from Western Togoland.

(2) The Togo Series, resting on the metamorphic crystalline basement rocks, is composed of quartzites, quartz-schists, mica-schists, and phyllites. It is the equivalent of Hubert's Atacora Series, and of Kitson's Akwapim Series.

(3) The Buem Series, faulted against the Togo Series, is composed of quartzites, quartzitic sandstones, conglomerates, hardened mudstones and phyllites, and contains in its older portion a considerable development of eruptive rocks, principally basaltic in composition. It is the equivalent of Hubert's Gourma Series, and of Kitson's Birrim Series.

(4) The Oti Series, resting unconformably on the Buem Series, is composed of arkoses, sandstones, mudstones, and conglomerates, with very subordinate calcareous beds. It appears to be derived chiefly from the Crystalline Metamorphic Series, and from the Buem Series. It is the equivalent of Kitson's Kwahu Series.

(5) The above conclusions are not new, having been established by several German observers, but the information published by them (except v. Ammon's descriptions of specimens collected by non-geological observers) is on the whole of too generalized a character to permit of critical comparison of the Togoland succession with that of surrounding regions. The foregoing paper is an endeavour to provide information, independently obtained, such as will not only substantiate the conclusions already formed, but also afford material which can be used to bring the geology of Western Togoland into line with that of other parts of West Africa.

EXPLANATION OF FIG. 4.

Magnification in each case 28 diameters.

(*a*) Buem Sandstone. North-west of Kolenu. Two rounded quartz grains are shown in a matrix of smaller angular grains, most of them of quartz, but some of the darker ones of felspar. Cement siliceous.

(*b*) Keratophyre, East of Sagada. Fresh phenocrysts of soda felspar, accompanied by small idiomorphic pale green augite crystals, patches of chlorite (south-west quadrant), and a little clear (?) secondary quartz (e.g. above an iron ore patch in the south-west quadrant) in a somewhat decomposed felspathic groundmass.

(*c*) Bostonite. Between Kpandu and Dukluja. Patchy crystals of soda felspar in many places arranged radially. The spaces between the crystals are filled with chlorite. Scattered throughout the felspar are tiny magnetite crystals.

The Limestone Hills of the Kinta Valley Tinfield, Federated Malay States: their Geology and Physiographic Origin.

By W. E. CAMERON, B.A., late Economic Mining Geologist F.M.S. Govt.

THE limestone hills of the Kinta Valley, standing up with white cliff faces from an almost level plain, form a prominent and picturesque feature of this prolific tinfield, and attract attention and present a varying scene as viewed from different points in the valley of the Kinta River. Their mode of origin has been the subject of marked divergence of opinion amongst geologists acquainted with them, as has also their age in relation to the series of metamorphic sediments found in the same valley.

Previous Opinions as to Origin.

The Geologist to the Federated Malay States Government, Mr. J. B. Scrivenor, as long ago as 1913 propounded the theory (*Geology and Mining Industry of the Kinta District, Kuala Lumpur*, 1913, p. 18) that these hills are "*huge blocks of the earth's crust that sank on to the granite magma relatively less than the surrounding rocks*" during the extrusion of the granite which forms the surrounding ranges, and Mr. Scrivenor gives an elaborate plan of the positions of the hypothetical faults bounding the several blocks that are supposed to have been the result of this unequal subsidence.

Dr. W. R. Jones has questioned the possibility of this method of origin of the limestone hills,[1] pointing out the large number of fault systems that Mr. Scrivenor's hypothesis would imply, the tremendous throw of the faults necessary to bring the upfaulted blocks into their present position, "*equal to the present height of these rocks above the general level of the valley-floor, which is formed of the same limestone,*" that is to say of an order of magnitude of at least 1,500 feet, and the absence of any reason "*why the limestone floor of the valley should sink into the granite magma, and leave these limestone hills as isolated heights*".

Dr. Jones ascribed the contour of these hills, their detached character, and their height above the surrounding plain, to "*uneven denudation of a strongly jointed metamorphic limestone and the subsequent mechanical and chemical denudation of the surrounding limestone*".

Mr. Scrivenor, however, as late as November, 1923, still maintained his first expressed opinion as to block-faulting being the main cause of the occurrence of these hills,[2] and adduced the following considerations in support of his contentions.

1. The distribution and height (of the hills) above the limestone floor of the tinfield.
2. Vertical limestone cliffs overlooking the granite of the Kerbau coulisse (the main granite range of the Peninsula, culminating in Mt. Kerbau at 7,000 ft.).
3. Small patches of phyllites lying between the base of the cliffs and the granite.
4. Occurrence of a brecciated iron deposit at the base of one of these hills.

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[1] "Secondary Stanniferous Deposits of the Kinta District": *Q.J.G.S.*, vol. lxxii, pt. 3, 23rd November, 1917; "Dredge Prospecting in the Kinta Valley": *Mining Journal*, London, 30th September, 1923.

[2] "Structural Geology of British Malaya": *Journal of Geology*, vol. xxxi, No. 17, 1923.

TOPOGRAPHY.

The limestone hills stand up as a series of prominent detached blocks out of an almost level plain. The plain is bounded on the east and west by abrupt granite ranges, forming a flat-bottomed valley, some 40 miles in length from north to south, some 5 miles in width at its northern end, and widening to some 8 miles in width at its southern end. It is drained from north to south by the Kinta River and its tributaries, the river flowing nearer the western edge of the valley.

On the east of the valley is a wall formed by spurs of the main range of the Peninsula, mainly composed of granite and rising to heights of 7,000 feet above sea-level. On the west is a similar wall formed by the detached Kledang Range, an elongated granite mass rising in several heights to over 3,000 feet above the sea.

The general level of the valley floor is from 30 feet to 150 ft. above the sea, diversified by the limestone hills rising to heights of up to 2,000 feet, and by lower rounded hills of quartzites, schists, and phyllites rising here and there to heights of 250 ft.

The limestone hills have generally perpendicular and often overhanging faces, and as a rule are separated from each other by a level area, adjacent hills being often parted by only a few yards of ground of no greater altitude than the general level of the plain, so that it is often possible to pass between the cliff faces of adjacent hills, rising to hundreds of feet above the plain, without ascending to heights above its general level.

The hills are of all dimensions, from small isolated roughly rounded or truncated blocks a few hundred yards in circumference and a few score feet in height to masses up to 8 miles in circuit and rising to heights up to 2,000 feet.

The larger masses of these limestone hills are characterized by the extreme irregularity of their outline in plan, being deeply indented by numerous bays, by which the very centre of the hills can often be penetrated between cliff faces of limestone, sometimes from several sides, without rising above the general level of the valley floor. They are also penetrated deeply by numerous caves leading in from the valley floor, and opening up at higher levels, which are largely made use of by the Chinese community for rock temples and even for dwellings.

In a few cases the lower ground between adjacent hills is occupied by the present main stream channels of the valley, flowing in gorges between precipitous cliffs, and is manifestly the result of the cutting down by those streams from a once much more elevated land surface, corresponding more nearly in height to the present summits of the loftier hills at probably 2,000 feet above the present stream courses.

In a great many instances, however, the division between adjoining hills shows no relation to the present stream channels, but cuts right across their direction. In these cases there is little doubt but that the present positions of the cliffs have been brought about by the ordinary weathering agencies of rain percolation and solution of the limestones acting along their pronounced vertical jointing and bedding planes, causing progressive flaking off of large detached blocks by undermining of their support.

GEOLOGY OF THE LIMESTONE HILLS.

The limestones of the cliff hills are crystalline and granular in texture and generally pure white in colour, though black and other coloured bands occur. They have practically the composition of dolomite in places, but sufficient analyses have not been made to show whether this characteristic is widespread or not.

The bedding planes are often obscured by deposition of secondary calcite, but numerous observations of well defined dips show that the limestones of the hills are regularly and evenly bedded, and have been in general only moderately flexured from the horizontal. In places this flexuring is more severe, and the beds have been momentarily thrown into sharp folds, and in some cases even reversely faulted.

Examination of the floor of the valley from which these hills rise shows that it is widely covered by recent alluvial gravels, sands, and clays, the products of denudation of the granites, quartzites, and schists, but that where the rock floor has been exposed by mining operations on these alluvial deposits, or where its undulations bring it above the level of the drift, or it has been cut into by stream action, it also is largely composed of limestone, and where not of limestone in great part by a highly contorted and schistose series of slates, quartz and clay schists and quartzites.

These limestones of the valley floor are, however, distinct in texture and general attitude from those of the hills, and in the structures imposed on them by earth movements. They almost invariably stand at high angles of inclination, with very varying directions of strike, the result of extremely severe folding and twisting of the beds. They do not show even and regular bedding like the limestones of the hills, but have been contorted, sheared, and brecciated by forces of much greater intensity than those to which the limestones of the hills have been subjected.

The contact of the upper limestones with those of the valley floor is as a rule obscured by talus from the cliff faces, but several of the smaller hills can be completely traversed around their bases, with numerous exposures of the steeply and often vertically dipping sheared and brecciated limestones underfoot, striking at the cliff faces of the gently inclined and regularly bedded limestones of the hills. In other cases the limestones of the hills are found lying on heavily folded and contorted quartzites, schists, and slates, and even overlapping the boundary between the heavily folded limestones and the metamorphosed clastic beds.

A large portion of the valley floor adjacent to and surrounding the limestone hills is thus seen to consist of an ancient plain of denudation cut out of the older heavily folded quartzites, schists and older limestones, overlain with pronounced unconformity by the newer limestones of the hills. These upper limestones were subsequently flexured to some extent during elevations and depressions, heavily jointed, and even faulted during these movements, and finally cut down by the present cycle of erosion till they now constitute a series of detached and, geologically speaking, rapidly disappearing residuals, resting on an uneven floor formed by the upturned and denuded edges of the much more highly disturbed and older rocks of the plain.

The limestone hills occur mainly along the east of the valley, the floor of which, as indicated by the position of the Kinta River along its western margin, slopes generally to the west.

Along the west of the valley occur areas of the gently dipping upper limestones below the level of the valley floor, which have not yet been cut right down to the basement on which they lie, as that basement in places here lies at a lower level than the present level of erosion of the Kinta River system.

At one position, however, the base of the upper distinctly bedded and gently dipping limestone of the upper formation can, in a mine working, be seen lying directly on the upturned edges of the heavily folded and sheared limestones of the lower formation.

FAULTING IMPOSSIBLE AS AN EXPLANATION OF THE LIMESTONE HILLS.

The occurrence of these limestone hills therefore bears a simple explanation, and it is not necessary to call in the aid of a series of purely hypothetical faults, of which there is no direct evidence, to account for their height above the plain. Such faults, to have been effective to the extent ascribed to them, must have been of the order of 1,500 feet at least in vertical throw, as was pointed out by Dr. Jones, in order to have pushed up these blocks to the heights that they now occupy.

Any faulting, therefore, of the magnitude involved would have brought the rocks of the older series, occurring generally at the level of the plain, up to heights far above the plain in the blocks that are supposed to have been elevated by that faulting.

Such is never the case, however. The limestone cliffs from base to summit are invariably made up of the gently dipping limestones, here and there flexured to some extent by horizontal pressure, but quite distinct in attitude and structure from the older limestones, and in a still more marked degree from the quartzites, schists, and slates occupying part of the same valley floor.

This relation between the limestones of the hills and those of the valley floor was not observed by either Mr. Scrivenor or Dr. Jones, and was only brought out by detailed mapping on a large scale, and by plotting of numerous dips and strikes wherever these could be observed. Its recognition, however, makes impossible of acceptance any block faulting of the magnitude postulated by Mr. Scrivenor, and shows that Dr. Jones's contention, that the form of the hills is due to the simple action of the ordinary processes of denudation on a strongly jointed limestone, is the correct one, the extent of that denudation in vertical range being, however, on the east of the valley at least, determined in great measure by the greater compactness and power of resistance to weathering of a floor of older limestone and metamorphic sediments on which the upper limestones lie.

Mr. Scrivenor's four reasons as given in his paper on the " Structural Geology of British Malaya " and quoted above, are as capable of explanation as a result of unequal denudation of a strongly jointed and comparatively gently flexured limestone lying on a floor of older heavily folded and sheared beds, as described above, as they are as a result of heavy block-faulting of the magnitude assumed by him, or even more so.

The distribution and height of the hills is not unusual when compared with the results of denudation of limestone in other parts of the world. The fact that vertical limestone cliffs overlook the granite of the main range is due no doubt to the same unequal effects of denudation referred to by Dr. Jones, acting in this case on rocks of two different attitudes towards weathering, limestone on the one hand and granite on the other, along their line of junction, the readily decomposing granite being weathered down to rounded hills on one side of the junction, while the limestone has been flaked off by solution along vertical joints into vertical cliffs on the other side.

The fact that small patches of phyllites lie between the base of the limestone cliffs and the granite is readily accounted for when it is appreciated that they are older and overlain unconformably by these gently dipping upper limestones. Mr. Scrivenor's necessity of accounting for their, in his view, extraordinary position by faulting was brought about by his regarding them as newer than the limestones of the hills.

The occurrence of brecciated iron deposits occurring at the base of the hills is an interesting fact that can be explained on quite other grounds than those inferred by Mr. Scrivenor. Iron lodes of considerable magnitude occur in several places on the floor of the valley in the older heavily folded limestones, but do not appear to have penetrated into the upper limestones of the hills. The brecciated beds occur in close proximity to these iron lodes, and the writer's explanation of their occurrence is that they are the results of denudation of the iron lodes of the older formations, spread out on the old floor of denudation described above on which the newer limestones were laid down, and that they are consequently much older than these limestones. This is at least as feasible an explanation as that they are the result of faulting, and to the writer, who has carefully mapped the outcrops of these brecciated iron ores and their parent iron lodes, it is the only reasonable one, and no evidence of their connexion with faulting was observed in the field.

AGE OF THE KINTA LIMESTONES.

The limestones forming the hills of Kinta and those of the bed rock of the valley have generally been assumed to be all of one age. Mr. Scrivenor, in his report, states that no fossil evidence of any homotaxial value has been found in these limestones in the Kinta Valley and that "*the age of the limestones cannot be learned from any palaeontological evidence that has been brought to light on the west side of the Main Range*", but has concluded that all the limestones are Carboniferous on account of their similarity with limestone containing recognizable Carboniferous fossils on the east side of the granite of the Main Range in Pahang.

The writer's survey of the valley during 1923, and part of 1924, has led to the conclusion, as shown above, that the limestones of the Kinta Valley belong to two distinct formations differing widely in attitude and in the structures imposed on them by earth-movements. lying in violently unconformable relation with each other, and consequently differing widely in age.

In an outcrop on the plain behind Chankat Pari, near Ipoh, in heavily folded and sheared limestone of the lower formation as recorded by Mr. Scrivenor, were found "*great numbers of what were probably once crinoid stems, and other organisms*", and it was on this evidence apparently that these limestones were considered the equivalents of the limestone and shales of the Raub series of Pahang, determinable on their fossil evidence as Carboniferous. The correlation does not appear very satisfactory, but indicates that the lower limestones are probably Carboniferous, and that the unconformably overlying upper limestones are post-Carboniferous.

The upper limestones are undoubtedly older than the porphyritic granite of the Kledang Range which has been found intruding them, and probably also than the granite of the Main Range which would appear to be of the same age as that of the Kledang Range.

Mr. Scrivenor, in his *Geology of South Perak*, advanced a late Mesozoic (probably Cretaceous) age for the granites of the main range, apparently on the evidence of intrusion of rocks carrying Triassic fossils by the granites in Pahang.

As far as I am aware there is no direct evidence of the relation of the upper limestones to the Triassic beds of Pahang and Singapore, but it seems probable that they are younger. All that can be said, however, with any degree of certainty in the present fragmentary and indefinite state of our knowledge of the geological history of the Peninsula is that they are probably much more recent than the Carboniferous and earlier than the Cretaceous.

On Senonian Ammonoidea from Jamaica.

By L. F. Spath, D.Sc., F.G.S.

(PLATE I.)

IN his paper on "The Yellow Limestone of Jamaica and its Mollusca" (Geological Magazine, Vol. LX, 1923, p. 345) Dr. C. T. Trechmann referred to an Upper Senonian fauna from shales at Providence, near Port Antonio, underlying a limestone with *Rudistae*. He recorded *Baculites* from the upper portion of these shales, and "rather low in the sequence" he collected some ammonites, one of which had been identified by the writer as belonging to the genus *Parapachydiscus*. The Shales at Providence had already been mentioned by the late Mr. Lucas Barrett [1] as containing *Baculites* and *Hamites*, and in his collection, now in the British Museum (Natural History), there are preserved a number of fossils including the *Pholadomya* and *Trigonia* he recorded and two fragments of *Hamites*. The matrix of these is the same as that of Dr. Trechmann's examples, namely a brown calcareous sandstone, and the "*Hamites*" in both collections belong to the same species, but Mr. Lucas Barrett's *Baculites* I have not been able to trace.

It is intended in the present paper to give a short account of these Jamaican Ammonoids, and the writer's acknowledgments are due to Dr. C. T. Trechmann for entrusting him with the description of these forms, now incorporated in the National Collection. It might be added that the only ammonite in Dr. Trechmann's collection that was sufficiently well preserved for off-hand determination, could at once be compared to *Parapachydiscus* of the *neubergicus* group, and the whole assemblage suggested affinity with such Upper Senonian faunas as for instance those described by the writer from Zululand [2] and Pondoland,[3] by Spengler [4] from Assam, and by Imkeller [5] from the Bavarian Alps, all with *Parapachydiscus*, "*Hamites*," and *Baculites*. This is not in accordance with the evidence of the echinoids,[6] but a renewed examination of the specimens has confirmed my previous opinion of the Upper Senonian age of the Jamaican Ammonoids here described.

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[1] In Sawkins, "Report on the Geology of Jamaica": *Mem. Geol. Surv.*, 1869, p. 78.

[2] "Cretaceous Cephalopoda from Zululand": *Ann. S. Afr. Mus.*, vol. xii, pt. vii, No. 16, 1921, pp. 217–73.

[3] "Upper Cretaceous Ammonoidea from Pondoland": *Ann. Durban Mus.*, vol. iii, pt. ii, 1921, pp. 39–56. "Senonian Ammonite Fauna of Pondoland": *Trans. Roy. Soc. S. Afr.*, vol. x, pt. iii, 1922, pp. 113–47.

[4] "Contributions to the Palæontology of Assam": *Mem. Geol. Surv. India, Pal. Indica*, N.S., vol. viii, No. 1, 1923, pp. 51–67.

[5] "Kreidebildungen und ihre Fauna am Stallauer Eck und Enzenauer Kopf bei Tölz": *Palaeontographica*, vol. xlviii, 1901, pp. 53–7.

[6] See Hawkins, "Some Cretaceous Echinoidea from Jamaica": Geol. Mag., Vol. LX, 1923, p. 215.

Family LYTOCERATIDAE Neumayr emend.

Genus Epigoniceras gen. nov.[1]

Epigoniceras sp. ind. (Pl. I, Figs. 2*a*, *b*.)

A small crushed ammonite (C. 25258) terminating in a septal surface, by its whorl-shape, smoothness, and suspicion of constrictions, seems to be referable to the group of "*Tetragonites*" *epigonus* Kossmat, for which the present new genus is proposed. A comparison of the suture-line of *Tetragonites timotheanus* (Mayor MS.) Pictet,[2] the genotype, with that of *Epigoniceras epigonum* (Kossmat), especially of the internal portions, demonstrates that the two stocks are merely heterochronous homoeomorphs.

The fragmentary *Epigoniceras* recorded by Spengler,[3] from a corresponding fauna from Assam, is more depressed than the form here figured, but owing to the crushing and distortion of its whorl-shape, exact specific identification is impossible.

Family PACHYDISCIDAE Spath.

Genus Parapachydiscus Hyatt.

Parapachydiscus aff. *stallauensis* (Imkeller) Spath. (Pl. I, Figs. 3*a*–*c*.)

1901. *Pachydiscus neubergicus* (Hauer) var. *stallauensis* Imkeller, loc. cit. (*Palaeontographica*, xlviii), p. 57, pl. iii, fig. 5.
1922. *Parapachydiscus stallauensis* (Imkeller) Spath, loc. cit. (*Trans. Roy. Soc. S. Afr.*), p. 123.

The fairly complete example (C. 25256) figured on Pl. I, Figs. 3*a*, *b*, is crushed, and the outline-section (3*c*) is diagrammatic and, perhaps, too inflated. The inner whorls and suture-lines also, unfortunately, are not preserved, but the presence, at intervals, of accentuated costae, oblique forward, is characteristic. Towards the end of the shell these primary costae are hardly more conspicuous than the two or three intercalated secondary ribs, some of which, however, remain very short. This type of untuberculate ornamentation is not found in the Lower Senonian *Nowakites*, nor in its derivative *Eupachydiscus*. The genus *Canadoceras* agrees with the forms of the present group of *Parapachydiscus* in the absence of umbilical tuberculation, but it has the peripheral ribbing projected strongly forwards.

P. neubergicus (Hauer) in Grossouvre's[4] interpretation is rather different from the present species, but a Haldem (Westphalia) specimen in the British Museum (No. 74233) labelled "*Pachy-*

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[1] Genotype: *Tetragonites epigonus* Kossmat: "Untersuchungen über die Südindische Kreideformation": *Beitr. Pal. Geol. Österr.-Ung.*, vol. ix, 1895, p. 135, pl. xvii, figs. 4*a*–*c*.

[2] See Spath, "Ammonoidea of the Gault": *Mon. Pal. Soc.*, (1921), 1923, text-fig. 6, p. 26.

[3] Loc. cit., 1923, p. 51, pl. iv, figs. 6*a*, *b*.

[4] "Les Ammonites de la Craie Supérieure": *Mém. Explic. Carte Géol. Dét. France, Rech. Craie Supér.*, ii, 1893, p. 207.

discus neubergicus?" and perhaps belonging to *Parapachydiscus stobiae* (Nilsson) Schlüter[1] is close to the present example. Spengler's "*Pachydiscus*" *assamensis*[2] differs mainly in its wider umbilicus. Nowak's[3] *P. kaliszanensis* and *P. bystrzycae,* also his *P. subrobustus* (Seunes) and *P. oldhami* (Sharpe), are comparable species. Nowak included *P. kaliszanensis* in the *isculensis* group (*Eupachydiscus* Spath), but it is here considered to be a *Parapachydiscus*, though this genus is still far too comprehensive.

Parapachydiscus cf. *gollevillensis* (d'Orbigny). (Pl. I, Figs. 3*d*, *e*.)

1841. *Ammonites lewesiensis* (Sowerby) d'Orbigny: *Pal. Franç., Ter. Crét.* (I), p. 336, pl. ci only.

1850. *Ammonites gollevillensis* d'Orbigny: *Prodrome de Pal.*, vol. ii, p. 212.

1922. *Parapachydiscus gollevillensis* (d'Orbigny) Spath, loc. cit. (*Trans. Roy. Soc. S. Afr.*), p. 122.

A second fragmentary example (C. 25257) of a *Parapachydiscus* (Pl. I, Figs. 3*d*, *e*), though poorly preserved, appears to belong to the group of *P. gollevillensis*, the genotype species. The differentiation of the costae into umbilical and peripheral portions, and their interruption along the middle of the ventral area, are marked, suggesting affinity with the species of this group discussed on a previous occasion. A closely comparable example is the "*Pachydiscus gollevillensis*" figured by Seunes[4] from the *Baculite* Limestone of the Cotentin.

There is little definite stratigraphical information with regard to these forms of *Parapachydiscus*, but Haug[5] has a zone of *P. neubergicus* as the upper division of his Maestrichtian, immediately below the Danian. It must be remembered, however, that no careful zonal collecting has yet been done in the Upper Senonian and higher beds of Mediterranean countries, and correlation of different areas such as that attempted by Seunes[6] is inexact and based probably largely on heterochronous elements of superficial resemblance.

Family NOSTOCERATIDAE Hyatt.

Genus GLYPTOXOCERAS gen. nov.

On a previous occasion[7] Forbes' *Hamites indicus* and *H. rugatus* were doubtfully included in the genus *Diplomoceras* Hyatt; but the restriction of this genus to the typical group of *D. cylindraceum* (d'Orbigny)[1] has now become necessary, so that a new genus is proposed for the Upper Senonian "*Hamites*", the genotype to be *Hamites* (*Anisoceras*) *rugatus* (Forbes) Kossmat.[2] This is probably connected with such loosely coiled *Bostrychoceras* as those referred to in the writer's Zululand paper,[3] and the resemblance to the equally "hamitid" group of *Diplomoceras cylindraceum*, less far removed from the *Lytoceras* ancestor than *Glyptoxoceras*, is merely superficial.

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[1] "Cephalopoden der Oberen Deutschen Kreide": *Palaeontographica*, vol. xxi, 1872, p. 56, pl. xvii, figs. 4–5.

[2] Loc. cit., 1923, p. 56, pl. iv, figs. 5*a–d*.

[3] "Untersuchungen über die Cephalopoden der Oberen Kreide in Polen. III": *Bull. Acad. Sci. Cracovie, Cl. Sci. Math. et Nat. B.*, 1913, pp. 353–62, pls. xl, xli.

[4] "Contribution à l'étude des Céphalopodes du Crétacé Supérieur de France": *Mém. Soc. Géol. France, Pal.*, vol. ii, 1891, p. 10, pl. v, fig. 2.

[5] *Traité de Géologie*, vol. ii, fasc. 2, 1907, p. 1170.

[6] Loc. cit., 1891, pp. 21–2.

[7] Spath, loc. cit. (Zululand, 1921), p. 256.

Glyptoxoceras cf. *rugatum* (Forbes). (Pl. I, Figs. 4*a–c*.)

1895. *Hamites* (*Anisoceras*) *rugatus* (Forbes) Kossmat, loc. cit. (*Beitr. Pal. Geol. Österr.-Ung.*, ix), p. 146, pl. xix, figs. 7*a*, *b*.

The three small fragments (C. 25259, 61, 62) here figured cannot be definitely identified, but there is resemblance to Forbes' species and its allies, e.g. the Pondoland *Hamites* (*Anisoceras*) *subcompressus* (Forbes) figured by Mr. H. Woods.[4] *Gl. retrorsum* (Schlüter)[5] is also close, and a Haldem (Westphalia) specimen in the British Museum (No. 62527), which is more closely costate than Schlüter's (larger) type and the present fragments, differs mainly in its blunter costation, though this may be a matter of preservation. In the Jamaican examples the ribs are as acute as those of an Aachen Greensand specimen (B.M. No. 83305), resembling both *Gl. roemeri* (Geinitz) Holzapfel sp.[6] and *Gl. aquisgranensis* (Schlüter).[7]

Family BACULITIDAE Spath.

Genus Baculites Lamarck.

Baculites sp. ind. (Pl. I, Fig. 1.)

The specimen here illustrated (C. 25260) contains at least four crushed fragments and impressions of a few more, but as the matrix is not only sandy but also metamorphosed, the preservation of the *Baculites* is rather poor. There are traces of suture-lines, and the largest example has about four crescent-shaped nodes such as are found in many species of the group of *B. incurvatus* Dujardin, though the other fragments seem to show more resemblance to the smooth Fox Hill species. The shape of the shell-section was probably compressed elliptical, far less inflated than that of *B. asper* (Morton) or *B. capensis* Woods, though owing to the crushing it is impossible definitely to identify the Jamaican specimens. A pre-

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[1] *Pal. Franç., Ter. Crét.*, i, 1841, p. 551, pl. cxxxvi, figs. 1–4.

[2] Loc. cit., 1895, p. 146, pl. xix, figs. 7*a*, *b* (B.M. No. R 10500, Geol. Soc. Coll.).

[3] Loc. cit., 1921, p. 256.

[4] "Cretaceous Fauna of Pondoland": *Ann. S. Afr. Mus.*, vol. iv, pt. vii, No. 12, 1906, p. 339, pl. xliii, figs. 2*a*, *b*.

[5] Loc. cit (*Palaeontographica*, 1872), p. 97, pl. xxx, figs. 5–7 (lectotype), described as *Ancyloceras retrorsum*.

[6] "Mollusken der Aachener Kreide": *Palaeontographica*, vol. xxxv, 1889, pl. v, fig. 5.

[7] Loc. cit., 1872, p. 102, pl. xxxi, figs. 6–9.

Senonian age of a bed full of large *Baculites* is, however, out of question, and in view of their association with *Glyptoxoceras* and occurrence about 100 feet or more above the fauna with *Epigoniceras* and *Parapachydiscus*, a Campanian or even later age is most probable.

Notes on some Analyses of Egyptian Igneous and Metamorphic Rocks.

By W. F. Hume, D.Sc., F.R.S.E., A.R.S.M., Director Geological Survey of Egypt; and
H. F. Harwood, M.Sc., Ph.D., A.I.C., Lecturer in Chemistry, Imperial College of Science and Technology, London.

PREFATORY NOTE.

For some years Dr. W. F. Hume had desired to obtain additional analyses of Egyptian igneous and metamorphic rocks for the purpose of a detailed investigation he proposed to make of their nature and distribution. The Chemical Department of the Egyptian Government was, however, too fully occupied on current work for Government contracts, and could not undertake the specialized analytical work necessary.

Later, Dr. Washington expressed his willingness to examine any Egyptian rocks that might be sent him, and in 1920, a series of gneisses were accordingly sent for analysis, the results of which will no doubt appear in due course. Meanwhile, Dr. Washington had issued his valuable work *The Chemical Analyses of Igneous Rocks*, in which were recorded all analyses hitherto made of Egyptian specimens.

In 1921, Dr. J. W. Evans, F.R.S., read some preliminary notes by Dr. Hume on the igneous and metamorphic rocks of Egypt, and in the course of his kind criticism of the manuscript, he referred to the entire absence of analyses of the rocks described. On Dr. Evans' advice, Dr. Hume communicated with Dr. Harwood, who volunteered to carry out the desired analyses. In the present paper are recorded the analyses made by Dr. Harwood to date, together with remarks on the bearing they may have on the structure of the rocks represented.

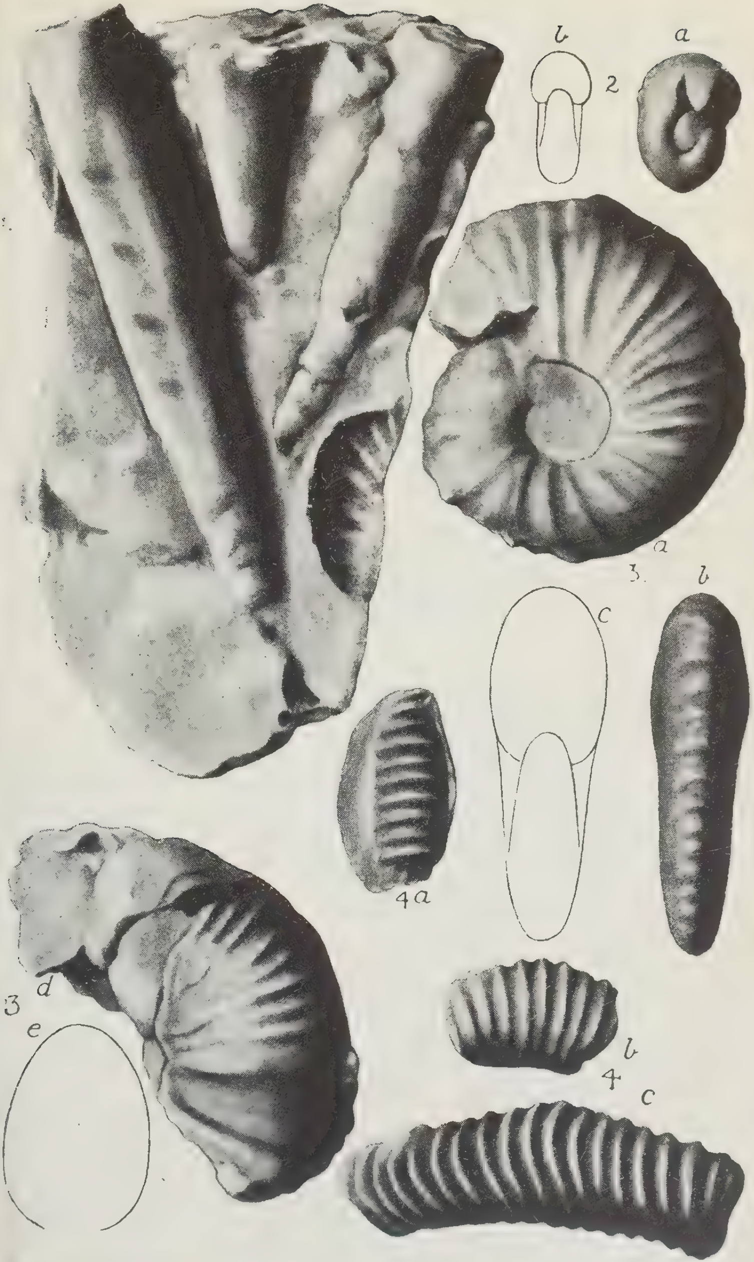
Two groups of rocks have been thus examined, five samples being of gneisses from typical exposures in the Eastern Desert, while one was of a well-marked basic rock from the same area.

The remaining five are part of a series which was fortunately collected in duplicate by Dr. Ball from the Aswan Dam at the time of its construction in 1899.

In the selection of the gneisses we had to depend on the existence of duplicates, the best specimens being in the collection of the Geological Museum in Cairo, and therefore not available for analysis.

ANALYSES OF EGYPTIAN GNEISSES AND ASWAN PLUTONIC IGNEOUS ROCKS.

Three of the gneisses analysed were taken from the region in the South-Eastern Desert of Egypt, where this type of rock is most



M. Woodward del.

SENONIAN AMMONOIDEA FROM JAMAICA.

[To face p. 32.

conspicuously developed, viz., within the area bounded to west and east by longitudes 34° and 36° E. respectively, and to north and south by latitudes 25° and 24° N. (see map, Fig. 1). The Wadi Shelul exposure is over 60 miles north-west of Gebel Abu Khrug in about latitude 25° 25′ N., and longitude 33° 45′ E.

Arranging the specimens in the order of their acidity, they are as follows :—

1. No. 1077. Gneiss of Wadi Shelul.
2. No. 10346. Gneiss of Wadi Abiad.
3. No. 11333. Gneiss of Wadi Lahami.
4. No. 10344. Hornblende-gneiss of Wadi Gimal.
5. No. 10570. Rock of gneissose aspect near Gebel Abu Khrug.

FIELD EVIDENCE.

The gneisses Nos. 2 to 5 were obtained from the region in S.E. Egypt where these rocks are most conspicuously developed. The exposure extends from Gebel Migif to Wadi Gimal, of which valley Wadi el Abiad is an important southern branch. Gneiss No. 5 was obtained from a gneissose mass occurring to the south of Gebel Abu Khrug. The majority of the gneisses occurring in Egypt may be classed either as granite-gneisses (crushed granites) or as diorite-gneisses (crushed diorites). From field observations, Nos. 1 and 2 would be placed in the first-named category, Nos. 3 and 4 in the second, while No. 5 is of an unusually basic type.

The analyses are as follows :—

	1. Wadi Shelul. No. 1077.	2. W. Abiad. No. 10346.	3. W. Lahami. No. 11333.	4. W. Gimal. No. 10344.	5. Near G. Khrug. No. 10570.
	%	%	%	%	%
Silica . . .	73·53	61·27	56·38	54·58	48·08
Alumina . . .	14·08	16·39	17·51	16·44	15·55
Ferric oxide . .	·46	2·14	2·91	1·95	·85
Ferrous oxide . .	1·19	2·74	4·32	5·70	6·37
Magnesia . . .	·37	2·63	2·77	4·80	12·68
Lime . . .	1·33	6·21	7·14	8·45	11·92
Soda . . .	3·73	3·87	3·81	3·29	1·04
Potash . . .	3·71	1·37	·82	·92	·21
Water above 110° .	·78	2·27	2·67	1·95	2·23
Water below 110° .	·25	·25	·59	·19	·16
Carbon dioxide .	·08	·38	·06	1·14	·16
Titanium dioxide .	·17	·35	·50	·53	·15
Zirconia . . .	·01	trace	none	trace	none
Phosphoric oxide .	·12	·17	·17	·17	trace
Chlorine . . .	trace	trace	trace	trace	trace
Sulphur . . .	·02	·02	·01	·02	none
Chromium sesquioxide	—	—	—	—	none
Vanadium sesquioxide	—	—	—	—	·03
Nickel oxide . .	—	—	—	—	trace
Manganous oxide .	·02	·11	·14	·15	·13
Strontia . . .	trace	trace	trace	none	none
Barium oxide . .	·02	trace	·02	none	none
Lithia . . .	trace	none	trace	none	none
	99·87	100·17	99·82	100·28	99·56

No. 6. The basic rock No. 10338 from Wadi Daut, which is associated with titaniferous hematite, had been diagnosed in the field as a gabbro. Its analysis is as follows :—

	%
Silica	52·53
Alumina	18·32
Ferric oxide	3·16
Ferrous oxide	5·01
Magnesia	5·56
Lime	10·34
Soda	3·21
Potash	·13
Water above 110°	·33
Water below 110°	·16
Carbon dioxide	none
Titanium dioxide	1·18
Zirconia	none
Phosphoric oxide	·22
Chlorine	trace
Sulphur	·01
Manganous oxide	·19
Strontia	none
Barium oxide	none
Lithia	none
	100·35

It will be of interest to compare the analyses of the Aswan series with those above given. They are as follows, the numbers being those of the Geological Museum, Cairo :—

	7.	8.	9.	10.	11.
	%	%	%	%	%
Silica	72·68	65·08	57·57	55·62	71·26
Alumina	12·27	13·95	14·03	11·87	14·24
Ferric oxide	1·88	1·69	3·12	2·66	·88
Ferrous oxide	1·02	4·38	6·35	8·56	2·84
Magnesia	trace	1·19	2·44	4·07	·80
Lime	1·20	3·40	5·11	11·25	2·15
Soda	2·22	3·39	3·69	1·57	2·73
Potash	7·55	4·28	2·80	·52	3·39
Water above 110°	·98	·98	·88	·86	1·14
Water below 110°	·20	·25	1·05	·30	·24
Carbon dioxide	none	none	none	none	none
Titanium dioxide	·09	1·04	2·30	1·78	·34
Zirconia	(?) trace	trace	none	none	·04
Phosphoric oxide	trace	·34	·81	·29	·09
Chlorine	trace	trace	trace	trace	trace
Sulphur	none	·01	·08	1·05	·07
Manganous oxide	·02	·12	·16	·20	·04
Strontia	none	none	none	none	none
Barium oxide	none	·08	·03	none	·03
Lithia	none	trace	trace	trace	trace
	100·11	100·18	100·42	100·60	100·28
Less O for S	—	—	·03	·39	·03
	100·11	100·18	100·39	100·21	100·25

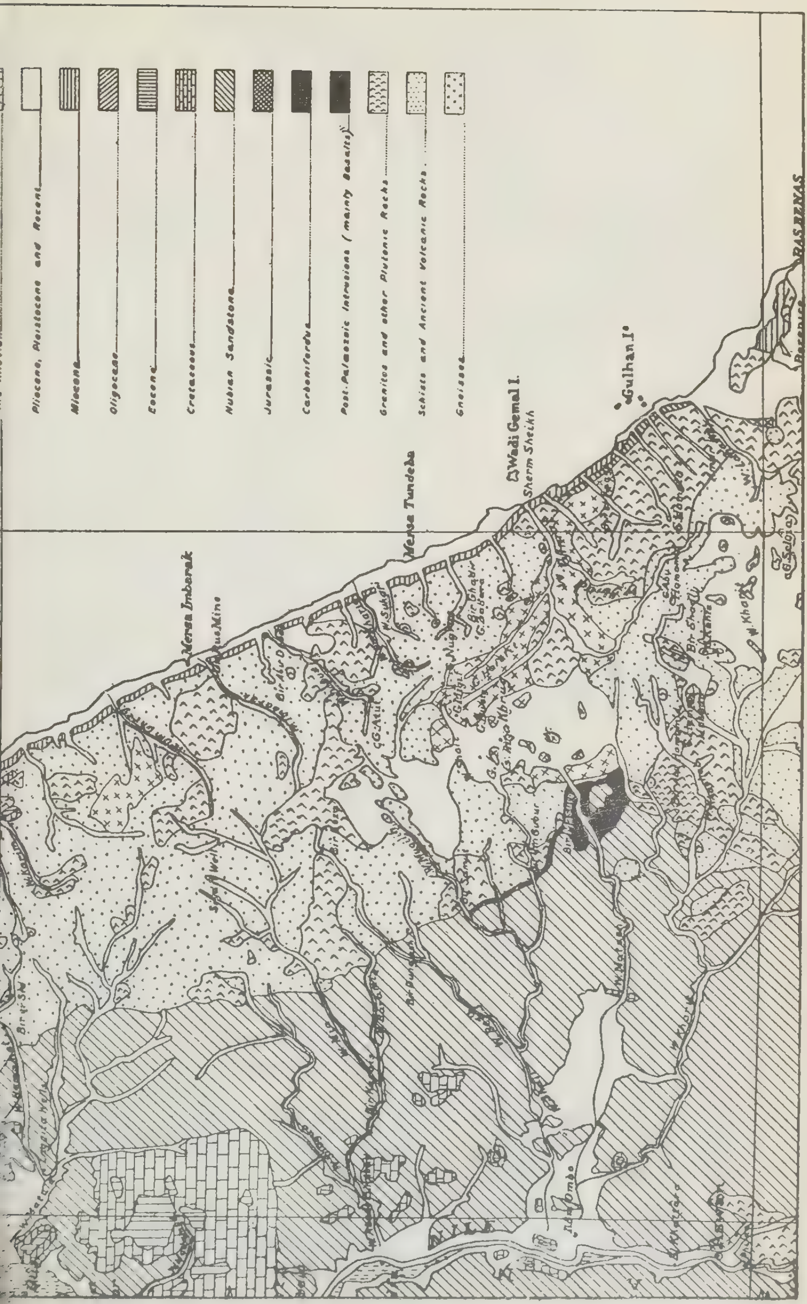


FIG. I.—Geological Map of Part of the South-Eastern Desert of Egypt.

7. Fine-grained red granite, No. 4489.
8. Syenitic granite, No. 4509 (1).
9. Syenite, No. 4515 (2).
10. Mica-diabase, No. 4485 (2).
11. Grey gneiss, No. 4485 (3).

An analysis of a typical sample of the well-known monumental granite of Aswan, will, it is hoped, be carried out later. Its omission from the scope of this paper is due to the fact that all the specimens in the Geological Museum of Cairo were on exhibit, and it has been singularly difficult to obtain other samples of suitable quality and guaranteed origin.

We give for purposes of comparison the three analyses of this rock recorded by Ball in his *Description of the First, or Aswan, Cataract,* these being by Delesse,[1] Scheerer,[2] and Wigner[3] respectively.

ANALYSES OF ASWAN MONUMENTAL GRANITE.

	Delesse, 1851.		Scheerer, 1866.	Wigner, 1878.
	%		%	%
Silica	70·25		69·95	68·18
Alumina	16·00		13·32	16·20
Ferric oxide . . .	2·50		n.d.	4·10
Ferrous oxide . . .	n.d.		4·90	n.d.
Magnesia	——		·66	·48
Lime	1·60		1·79	1·75
Soda	——		3·31	2·88
Potash.	——		3·47	6·48
Loss on ignition . .	·65		——	——
Alkalis and magnesia by		TiO_2	·95	n.d.
difference . .	9·00	MnO	n.d.	trace
		Water	1·27	n.d.
	100·00		99·62	100·07

GRANITES AND GRANITE GNEISSES.

Comparing the various results, it is at once noticed that the monumental and fine-grained granites of Aswan, as also the granite-gneisses of Shelul (No.1) and Aswan (No. 11), form a series closely comparable among themselves. As regards relationships, Dr. Ball states that the fine-grained rock shows distinctly more signs of crushing than the coarse-grained variety. It is frequently so highly crushed as to pass into a gneiss. Orthoclase is the dominant mineral in these granites, quartz forming only one-sixth to one-eighth of the whole. Hornblende varies in amount, and is generally absent in the fine-grained varieties. Biotite is also more common in the coarse than in the fine-grained granite.

The syenitic granite (No. 8) from Aswan, is obviously transitional to the syenite proper, as shown by the higher percentage of magnesia and iron oxides. The high percentage of titanium is obviously attributable to the presence of sphene, and the increase in the phosphoric oxide content indicates a larger amount of apatite.

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[1] *Q.J.G.S.*, 1851, pp. 9–13. The specimen was from a piece of the rock in the Louvre.

[2] Quoted in Roth's *Beiträge zur Petrographie*, 1869, p. xiv.

[3] H. H. Gorringe, *Egyptian Obelisks*, London, 1885, p. 161.

The syenite (No. 9) has been described and figured by Dr. Ball.[1] Diminution in the quartz content is indicated by the reduction in the percentage of silica. Orthoclase is still the predominant mineral, but oligoclase is relatively more abundant than it is in the granite, these facts being in harmony with the decrease in the percentage of potash and the increase in that of lime. The rise in iron oxides and magnesia indicates increase in ferro-magnesian constituents. " Of these, biotite remains an important constituent, though less abundant than the hornblende ; the latter is present in considerable amount, and gives the dark colour to the mass. The specific gravity of the rock rises from 2·65 in the normal granite to 2·84 in the true syenite."

The great increase in titanium oxide is easily explained by the fact that " sphene is constantly present in small quantity, sometimes in its characteristic wedge-shaped idiomorphic forms, but more usually in rounded grains. Ilmenite is also present in considerable quantity in small opaque grains ".

The high content of phosphorus is due to the presence of numerous crystals of apatite enclosed in the orthoclase, as indicated in Dr. Ball's plate vii, figs. 1 and 2. The description is as follows :—" The felspars frequently contain enormous numbers of minute prisms of apatite, and fairly large crystals of the same mineral, always in well-defined idiomorphic forms, are scattered among the other minerals." A comparison of the analysis of this rock with the average figures for all syenites, and for alkaline syenites, as given by Daly,[2] indicated that this rock is more basic in character than the average syenite (see below).

	Aswan Syenite. (Harwood.)	All Syenites. (Average of 50 analyses, Daly.)	Average alkaline syenites. (Daly, 23 analyses.)
	%	%	%
Silica	57·57	60·19	61·99
Alumina	14·03	16·28	17·93
Ferric oxide . . .	3·12	2·74	2·22
Ferrous oxide . . .	6·35	3·28	2·29
Magnesia	2·44	2·49	·96
Lime	5·11	4·30	2·55
Soda	3·69	3·98	5·54
Potash	2·80	4·49	4·98
Water	1·93	1·16	·76
Titanium dioxide . .	2·30	·67	·56
Phosphoric oxide . .	·81	·28	·14
Sulphur	·08	—	—
Manganese oxide . .	·16	·14	·08
Barium oxide . . .	·03	—	—
	100·42	100·00	100·00

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[1] J. Ball, *Aswan Cataract*, pp. 77–9, pl. vi, figs. 3, 4 ; pl. vii, figs. 1, 2.

[2] Daly, *Igneous Rocks and their Origin*, pp. 20, 21.

MICA-DIABASE OF ASWAN.

With the syenite may be compared the mica-diabase No. 10. (See Ball, loc. cit., p. 86, and pl. x, figs. 1 and 2.) The increase in the percentage of lime is due to the nature of the felspar, which is almost entirely andesine, and forms about half the rock in the slide studied.

It occurs as clear lath-shaped forms, showing repeated twinning. Ball determined the felspar as andesine by noting that the extinction angle in sections perpendicular to the brachypinacoid was about 18°. There is a notable increase in the magnesia and iron oxides, due to the abundance of a very pale-brown, slightly pleochroic augite occurring in allotriomorphic forms and rounded granules. "The somewhat less plentiful biotite is brown, altering to hematite, limonite, and chlorite : the flakes are frequently nearly filled by the opaque iron oxides. Hornblende is only sparingly present as an accessory constituent. It is green in colour, and forms irregular crystals with well-marked cleavages." Apatite is relatively abundant as well-defined hexagonal crystals. Pyrite and pyrrhotite are present in considerable amount, and these minerals are adequate to explain the high sulphur content of the rock. For comparison with the Aswan syenite and mica-diabase, we have the gneisses of Wadi Abiad (No. 2), Wadi Gimal (No. 4), and Wadi Lahami (No. 3). The above syenites and diabase may to a certain extent be compared with the series of gneisses as developed in Wadi Gimal (and its tributaries). The gneissic region between Gebel Migif and Wadi Gimal (see J. Ball, *Geography and Geology of South-Eastern Egypt*, 1912, pl. xx) is occupied by two main types of gneiss, one being a biotite-gneiss, which suggests a foliated biotite-granite. This rock is veined in a remarkable manner by pegmatite dykes which trend north-east and south-west. The other type is a hornblende- or diorite-gneiss. Analysis No. 2 is of the biotitic, and analysis No. 4 of the hornblendic variety.

Analysis No. 3 is a diorite-gneiss from a very complex series of rocks exposed in Wadi Lahami, further to the south.

If we first compare the analyses of the two Wadi Gimal types, we note that the hornblende-gneiss shows reduction in silica and a marked increase in ferrous oxide and magnesia, with a less noticeable increase of lime. The Wadi Lahami gneiss, on the other hand, occupies a position intermediate between the two Gimal varieties.

If, on the other hand, we compare these rocks with the syenitic granite and Aswan syenite, we find the Eastern Desert gneiss distinctly richer in alumina, and all show higher percentages of magnesia and lime. On the other hand, the Aswan granites show a higher content of potash and phosphoric acid.

From these results we might expect that the Aswan syenitic rocks would contain a greater relative percentage of orthoclase and apatite ; whereas the Eastern Desert gneisses would show a greater abundance of plagioclase felspars and ferro-magnesian silicates.

The more basic gneiss (No. 4) of Wadi Gimal has been described and illustrated by Dr. Ball,[1] who notes that the microscopic slides show plagioclase and green hornblende in about equal proportions, together with some quartz and small amounts of biotite, sphene, iron oxides, and apatite.

"The hornblende is very fresh-looking, in strongly pleochroic (yellowish to deep blue-green) straggling crystals, aggregated along the foliation-planes; the crystals, though variously orientated; show a tendency to lie with their cleavages in the direction of foliation. A very striking feature of the slides is the abundance of small grains of felspar in the hornblende, giving the green crystals a perforated appearance in ordinary light. The felspars, which are likewise fairly fresh, are much smashed up, forming with the quartz a mosaic between the irregular bands of hornblende; the grains often show undulose extinction. Biotite, of a warm brown colour where not bleached, is sparingly mixed with the hornblende. The sphene is in small rounded grains, mixed with, and sometimes containing, granules of ilmenite; the grains show a tendency to form little aggregates, sometimes in the hornblende, and sometimes in the felspathic portions of the slide. One or two stumpy grains of apatite are enclosed in the felspars, but this mineral is extremely scarce in the slides examined, and does not show its usual long prismatic habit."

Taken together, the analysis and slide indicate that the mineral composition of the more acid type of the Wadi Gimal gneiss obtained in Wadi Abiad (compare Nos. 2 and 4) is really similar to that of the Wadi Gimal rock, but the plagioclase felspars (too altered for closer determination) are in great excess. The reduction in the percentages of lime, magnesia, and iron oxides is a measure of the reduction in the ferro-magnesian silicates, which are green alteration products of biotite and hornblende. Quartz is present, but forms less than a sixth of the whole.

The Lahami gneiss No. 3 is a highly-foliated variety of diorite-gneiss, but no slides have been made of it. From the hand-specimen and the analysis it is concluded that it is a variety intermediate between the more acid and more basic members from the Wadi Gimal area.

GABBROS IN THE EASTERN DESERT OF EGYPT.

Analyses No. 5 and 6 are representative of a very important series of basic rocks, the importance of which may be touched upon here. Ball [2] has mapped wide areas in the South-Eastern Desert, near the borders of the Red Sea between Ras Benas and Halaib, as being occupied by such basic and ultrabasic rocks. This region is of particular petrographical interest, for, adopting the nomenclature of Suess, the Sinai type of rocks are developed on a large scale. These include the peridotites and serpentines of St. John's Island and Gebel Gerf, and a large series of gabbros. Sporadic occurrences have been noted further to the north-west, the occurrences at Abu Khrug and Wadi Daut being of this nature. The Abu Khrug variety was regarded as forming part of the gneissic series, but further study on the spot might lead to a modification of this view. The Abu Khrug gabbro has perhaps a somewhat unusually high percentage of magnesia ; on the other hand, the one from Wadi Daut displays no very striking difference from the average given by Daly.[1]

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[1] J. Ball, *Geography and Geology of South-Eastern Egypt*, p. 334, fig. 53, and pl. xxv.

[2] J. Ball, *Geography and Geology of South-Eastern Egypt*, 1912, see pl. xx.

The gabbro region is interesting, not only from the point of view of its varied petrography, but also from its possible economic significance. Nickel ore and gem peridots have been found in some quantity at St. John's Island, platinum has been noted, chromite might be looked for, and several ancient gold mines are situated near the junction between these basic rocks and the granites. It is still too early to generalize as to the latter being mainly so situated in Egypt. The present series of analyses strongly emphasizes the igneous origin of the gneisses in Egypt, and suggests that in the Wadi Gimal the two groups, one more acid and the other more basic, are in reality differentiations of the same magma, their characters being determined by the abundance or otherwise of the ferro-magnesian silicates.

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[1] Daly, loc. cit., p. 28.

REVIEWS.

THE EARTH: ITS ORIGIN, HISTORY, AND PHYSICAL CONSTITUTION. By H. JEFFREYS. pp. ix+278, with 8 text-figures. Cambridge University Press, 1924. Price 16*s*. net.

THIS is an important book. It forms an enlargement upon part of the matter of Jeans' book on Cosmogony, namely upon one astronomical system (the Solar system) with special reference to one body of that system (the Earth). Mathematical Geology is a new study; it is connected with many different sciences, and this forms one of the difficulties of the subject. This book should prove extremely useful to those working in this field. The general aim of the book is to obtain quantitative estimates, and considerable grasp of and insight into the problems discussed is shown by the author in being able to use the method of neglecting small quantities.

The scene is laid in the usual absolute space, time, and matter. The author mentions that he is making an extrapolation of physical laws from the exterior to the interior of the Earth, but no mention is made that he is extrapolating them to a much greater extent backwards in time; also in staging the theory in absolute space, time, and matter, he is using a concept which works well enough for "small" events. The reader must form his own opinion as to whether it is likely to prove so useful for "large" events.

The book begins with an account of the nebular hypothesis, and then gives a theory of the birth of the planets from the sun by tidal disruption due to a passing star, supposed the more massive of the two. The large discrepancies in properties between the major and minor planets do not appear altogether satisfactorily explained by this theory. No accommodation is given for planets knocked off the star by, and captured by, the sun. Presumably this would give the sun two sets of planets, inner and outer having come from itself and from the star respectively, and having different properties. If the sun were more massive and denser than the star, presumably the inner planets would be small and dense, and the outer large and less dense. More might be said about the constitution of giant stars as several points concerning them are fundamental for the theory given.

The book presents several conclusions of great interest to geologists. In the first place it is shown that whatever the earliest history of the earth may have been, nebular or planetesimal, it must necessarily have passed through a liquid phase. Hence the modern theories of petrogenesis are applicable. It may be noted that no account is given of the principles of magmatic differentiation, which have so important a bearing on the distribution of density within the earth. Reference might well have been made to the excellent summary given in Goldschmidt's *Stoffwechsel der Erde.*

A study of the history of the moon indicates that separation from the earth, if it ever occurred at all, must have taken place about the time when solidification was starting. This seems to be too early to have much bearing on the present distribution of land and sea, although a stripping off of part of the primary crust might have had notable effects. Mention should be made that no planet other than the earth could have had a moon born by tidal resonance.

The theory given of the zodiacal light will not be shared by all readers. The statement that the moon undergoes no denudation is correct, but it must suffer wear from bombardment by meteors and temperature changes. No mention is made of the effect on the surface of the earth when it reached 100° C. and the sea came down in rain.

From an excellent discussion of the phenomena of radio-active disintegration in rocks, it is concluded that the age of the earth, that is, the lapse of time since any considerable degree of solidification set in, must lie between $1{\cdot}3 \times 10^9$ and 8×10^9 years. This seems to allow ample time for any amount of evolution, both inorganic and organic.

The account given of the properties of solids is open to criticism, especially the author's use of the term "isotropic". This word is largely employed by geologists and mineralogists with reference to the optical properties of the crystals of the cubic system, but this use is quite indefensible. A crystalline substance cannot be isotropic in the general sense, which implies the absence of any vectorial characters and the possession of a homogeneous structure; and this is certainly not true of cubic crystals. Further, the author's ideas as to devitrification are by no means clear.

Finally, the get-up of the book maintains the high standard of the publishers.

S. W. P. S.
R. H. R.

DAS VULKANGEBIET AM NORDENDE DES NYASSA ALS MAGMATISCHE PROVINZ. By DR. E. LEHMANN. Supplementary volume of *Zeitschrift für Vulkanologie*, 1924: 209 pp., with VII plates, and folding map.

THIS is a petrographical study of material collected by Bornhardt, Dantz, and Scholz in the course of their several explorations, and it is prefaced by an account of the geology of the district, written by F. Behrend. Vulcanicity here is directly related to a part of the "Rift Valley" system of East Africa, and the igneous rocks, like all those associated with this tectonic type, are of strongly alkaline nature. They are here grouped under three chief heads: (*a*) leucocratic, including trachytes, phonolites, and kenyites, besides some dykes of tinguaite and bostonite; (*b*) intermediate (as regards the proportions of light to dark minerals), viz. trachydolerites and tephrites; (*c*) melanocratic, including atlantites, essexite-basalts, and basanites. It might perhaps be better to discard the hopelessly debased term "trachydolerite". The author prefers to redefine it, and to separate, under the new name "atlantite", the denser rocks rich in the dark minerals, including olivine.

A full description of the rocks is supplemented by twenty-seven chemical analyses, and these are subjected to elaborate manipulation of the kind which is now becoming customary. Those who view with some solicitude the prospect of petrology becoming a branch of arithmetic, may take a certain comfort from the very multiplicity of the schemes put forward. We miss here our old friends Osann and "C. I. P. W.", but each analysis is dealt with in the fashion of Hommel, of Wolff, and of Niggli. This seems rather superfluous, for the author gives in addition his own method of treatment, the chief feature of which is an attempt to render the actual mineral composition of each rock—the "mode" as contrasted with the "norm". A theoretical discussion follows, which traverses the whole field of magmatic differentiation, and is of frankly speculative nature. Finally, there is a brief section on the distribution of the several groups of lavas and their succession in time, which leads to no very definite conclusions. A comparison, from the petrographical side, of this district with others lying farther north would have added to the value of what is a notable contribution to our knowledge of East African volcanic rocks.

A. H.

THE FIRST ONE HUNDRED YEARS OF AMERICAN GEOLOGY. By G. P. MERRILL, Head Curator of Geology, U.S. National Museum. Yale University Press, 1924. (Published in Great Britain by Milford, Oxford University Press. 773 pp., 36 plates, and 130 figures. 27*s.* 6*d.* net.)

THIS volume on the history of American Geology brings together materials collected and published by Dr. Merrill in three previous publications of historical character, but here supplemented by additional material. Historical data of this sort are always scattered and involve much labour in bringing together, a task for which few men are either qualified, or have the time and inclination to undertake. Dr. Merrill has thus rendered a great service to the science.

The period covered is from 1785 to 1885, and the arrangement is chronological, the subdivisions being eras, which are roughly decades. The first two, the Maclurean, 1785–1819, and the Eatonian, 1820–1829, are named after the leading workers of the respective periods. The next five chapters are the successive eras of State Surveys, 1830–1880, followed by the era of National Surveys, 1880–1885, which marks the establishment of the United States Geological Survey. The remaining five chapters deal with special problems that were widely discussed during the period of the History. The chapter on "The Development of the Glacial Hypothesis" is of universal interest to geologists. The Appendix is composed of correspondence among the geologists of the period. The letters pertain to matters in the history and throw many interesting side-lights upon the men themselves.

Brief summaries of the papers of the various workers are given, with quotations, where they would best illustrate the author's meaning, and also brief biographical sketches, including portraits of 126 contributors to American Geology. The arrangement of the book being chronological, there is no sequence in the subject matter, the papers on widely varying subjects which appeared during each year being placed together. The author has inserted cross-references where there is evident connexion with some previous paper. The chapters on special subjects, on the other hand, trace the development of the problem through its history and furnish a connected story.

The early portions of the book bring out forcibly the hardships of the pioneer in geological work, and the state of scientific knowledge about rocks, igneous activity, mountain-making, origin of physiographic features, and the use of fossils in stratigraphic work. The influence of the Mosaic doctrine upon geologic thought is evident in this period also. The evolution of geologic thought during the entire period is shown to have been slow and laborious. Yet the science progressed, the individualism of the earlier part of the period giving way to more organized and co-operative work during the last of the century.

The book is stimulating and should be read by all young geologists (and many older ones) because, in addition to the historical background given, it teaches so forcibly tolerance of the views of others, and points out the value of a co-operative spirit.

It is to be regretted that so fundamental a part of geology as mineralogy should have been so seldom touched on by the author. His views in regard to including it are apparently expressed in the following comment on Schiel's work, p. 317, "The report contains scarcely anything of value from a geological standpoint, being mainly mineralogical and lithological, though a few invertebrate fossils are described and one fossil fish . . ." Also the bibliographic value of the book would have been increased had the original references been given.

This volume was much needed by American Geology to stand alongside Geikie's *Founders of Geology*, Woodward's *History of Geology*, and Zittel's *Geschichte der Geologie und Paläontologie bis Ende des 19 Jahrhunderts.* It is especially appropriate that the first volume published by the McMillan Memorial Publication Fund should have been this valuable History of American Geology by Dr. Merrill.

W. A. T.

THE DOWNTONIAN FAUNA OF NORWAY. I. ANASPIDA. With a geological introduction. By JOHAN KIÆR. Videnskapsselsk. Skrifter, I. Mat.-Nat. Klasse, No. 6. pp. 1–139, plates i–xiv. Kristiania, 1924.

THIS work is the first part of a monograph on the Downtonian fauna discovered at Ringerike in the Christiania area. The fauna consists of Fishes belonging to the Coelolepidae, the Cephalaspidae and the Anaspida; of Merostomata represented by *Eurypterus*, *Pterygotus*, *Stylonurus*, etc.; and of Crustacea belonging the genera *Ceratiocaris* and *Dictyocaris*. The fauna resembles that of the Downtonian of Scotland, but not so closely as appears at first sight. The sandstones of the Downtonian show ripple-marks and the shales sun-cracks, indicating shallow water and periodical drying. Unlike the underlying Ludlow Beds no undoubted marine fossils are found in the Downtonian, and it is believed that the Fishes, Merostomes and Crustacea lived in fresh-water. The excellent state of preservation of the fossils has enabled the author to make important additions to our knowledge of the structure and relationship of the Anaspida. The second part of the work will deal with the Cephalaspidae and Coelolepidae; the third part with the Merostomata; and the fourth part with the Crustacea.

DIE SCHOLLEN DER NORDDEUTSCHEN MORÄNEN. By Dr. G. PETERSEN, (Trier). Fortsch. d. Geol. u. Pal., Heft 9, pp. 179–274, with 1 figure and a map. Berlin, 1924.

THE word *Scholle* is here used to describe large blocks of sedimentary rock lying isolated in glacial deposits at a greater or less distance from their original position. Many examples of such are known in England, as at Trimingham, Cromer, Ely, and Catworth (Hunts), as well as in south Lincolnshire and Bedfordshire. In this work a list is given of 459 such occurrences in Germany. The largest known example is said to cover about 2,000 acres, and is from 50 to 65 feet thick, but most of them are of trifling size, and for the majority no measures of thickness are available.

One of the author's main objects in this memoir is to show that such blocks, having been sheared off by the ice-sheet, indicate projections of the surface and therefore earth-movements in Pleistocene times. This argument does not carry much weight, but incidentally a useful discussion is given of the tectonics of parts of North Germany, especially the Saxon folded area. In this discussion the term Hercynian is employed to indicate a N.W.–S.E. strike, a usage which will be new and puzzling to British geologists. The epochs of the phases of folding in this area should have an important bearing on the tectonics of S.E. England, but do not appear to have been as yet much considered from that point of view.

A SKETCH OF THE GEOLOGICAL HISTORY OF THE CHAROPHYTA. By JAMES GROVES and G. R. BULLOCK-WEBSTER. 8vo. (Reprinted from British Charophyta, vol. ii, Ray Society.) London, 1924.

THIS extremely interesting history of *Chara* seems likely to be overlooked by geologists because its place of publication is usually associated with recent organisms.

The authors discuss (and figure many) the numerous bodies that have been placed among the Characaeae from Silurian times to Pleistocene, and give their opinion on their position. It seems that the earliest undoubted Chara remains date from Jurassic times, though the Rhynie Chert fossils (Devonian) " may well belong to that group ". A bibliography accompanies the paper, which will be of great value to all who are interested in these well-known fossils.

C. D. S.

The Cambridge University Press has just published *A History of British Earthquakes*, by Dr. C. Davison, in which the author's aim has been to compile a catalogue of all known British earthquakes, to trace the zones in which crust-changes have recently occurred and in which the faults are yet alive, and to discover some of the laws that rule the growth of faults.

REPORTS AND PROCEEDINGS.

GEOLOGISTS' ASSOCIATION.

5th December, 1924.

" The Reading Beds of Lane End, Bucks, and their bearing on some unsolved problems of London Geology." By S. W. Wooldridge, M.Sc., F.G.S., and D. M. C. Gill, B.Sc.

The history of research and speculation on this area is briefly reviewed. Nearly 20 years ago H. J. Osborne White described quartzose gravels as occurring in the Reading Beds here, but in recent years his interpretation of the facts has been questioned. The present paper redescribes the outlier, recording certain new sections which are now visible and giving results of special excavations made at critical points on the outcrop. The authors are of opinion that the new evidence puts the correctness of White's inferences beyond question. Certain alternative explanations of the facts are discussed and rejected and the general conclusion is reached that Lower Cretaceous material is present in the Reading Beds. The Lane End outlier is regarded as preserving a relic of a marginal facies of the Reading Beds, formerly widespread. The probable original extent of this facies is discussed and confirmatory evidence of its existence is adduced from areas to the west. Its petrography and the apparent provenance of its constituents open up large questions as to the origin of the Tertiary sediments generally, and necessitate some revision of current ideas as to the progress of Tertiary denudation and the evolution of the Chiltern escarpment. Finally, the beds of Lane End type are considered as a possible source of part of the Pre-glacial Pebble Gravel of the London area.

EDINBURGH GEOLOGICAL SOCIETY.

15*th October*, 1924.

1. "Note on the Igneous Geology of Ardsheal Hill, Kentallen." By Dr. F. Walker, B.A., and A. M. Cockburn, B.Sc. Communicated by James Lunn, B.Sc.

In a short preliminary paper it was demonstrated that the summit of Ardsheal Hill (about 1 mile S.W. of Kentallen, Argyll) is made up of five rock types, mentioned below, which form a single igneous mass intrusive into the Cuil Bay Slates and Appin Phyllites :—

1. Olivine-basalt, with much orthoclase, grading into (2).
2. Porphyritic kentallenite.
3. Appinite, passing locally into hornblendite.
4. Hornblende-porphyrite, grading locally into malchitic and lamprophyric modifications.
5. Granophyre.

The first three types are intimately associated, forming numerous "Schlieren" with little chilling, which points to "fluxion in a magma which was heterogeneous at its time of intrusion". The porphyrite, however, is chilled against both basalt and appinite, and is therefore of later age than these. The relation of the granophyre to the other types is as yet unknown.

During the investigation, three new bosses of igneous rock were discovered :—(1) A small boss of kentallenite in a burn on the east slope of the hill ; (2) two small bosses of augite-diorite a little higher up the same burn, one of these bosses showing a peculiar association with quartz-porphyrite and quartz-diorite. In addition, the small boss above Duror Inn mapped as diorite was found to be a granodiorite.

It is hoped that further investigation will throw more light on these curious associations of rock-types.

2. "Exhibition of Rock Specimens from Central Norway, with Geological and Orographical Maps." By J. R. Leslie Gray.

The specimens, in the main, were of metamorphic origin, and most of them had been obtained from the moraines of existing glaciers.

A series of maps illustrating the topography and geology of the area was also shown.

19*th November*, 1924.

1. "Observations on the Geology of the Island of Lewis." By J. Wilson Dougal, B.Sc.

This paper was based upon a large number of specimens collected over many years in the Outer Hebrides. The oldest rocks are the Archaean gneisses, which are markedly crystalline and apparently of deep-seated origin. These, in Lewis, seem mainly to be of acid facies, but some rocks have been found in the neighbourhood of Keose (perhaps intrusive in the gneiss) which have been determined as of true ultra-basic type. Intersecting the gneiss are many pegmatitic veins and intrusions of fine-grained, grey, granular rock, the latter upon examination proving in some instances to be typical beerbachites such as have been described by Dr. Flett from the Lizard, and by Dr. Dixey from Sierra Leone. A microcline-granite occurs at Mealasbhal, apparently resembling that formerly noted at Carloway.

Later than the formation of the gneiss is a great belt of flinty crush rock, first discovered by the author in 1905, and subsequently traced by him throughout the Long Island for over a hundred miles. The curious character of this material has been a subject of much discussion. Formerly regarded by some as attributable to hypogene action, it seems likely that the vitrification observed was in large part merely a molecular disordering due to fine grinding. But it is not conceived that such a process of intense milling could take place without the generation of considerable frictional heat. The flinty crush rock does not seem formerly to have been in a condition of thorough igneous fusion because evidences of crystallization from a homogeneous liquid are extremely rare or indeed entirely absent.

2. "Exhibition of Specimens of the Lateritized Norite of Sierra Leone." By Major J. S. Bisset, R.E., Scottish Command.

Having given an account of the topography, geology, and climatic conditions of the colony, Major Bisset then described the mode of occurrence and processes of development of the laterite. Here, as elsewhere, the details of the intra-lithic chemistry of the transition from norite to laterite are obscure, but the resultant effects were suitably and typically represented by the specimens shown. Economic applications of laterite in Sierra Leone were illustrated by photographs.

3. "Exhibition of Specimens of 'Fossiliferous' Monchiquite from Earnscleugh, Lauder." By David Balsillie and John Mactaggart, Royal Scottish Museum.

The monchiquite of Earnscleugh has recently been carefully described by Dr. Frederick Walker. The specimens exhibited demonstrated one additional point of interest, viz., that xenolithic fish remains are of not infrequent occurrence in the rock.